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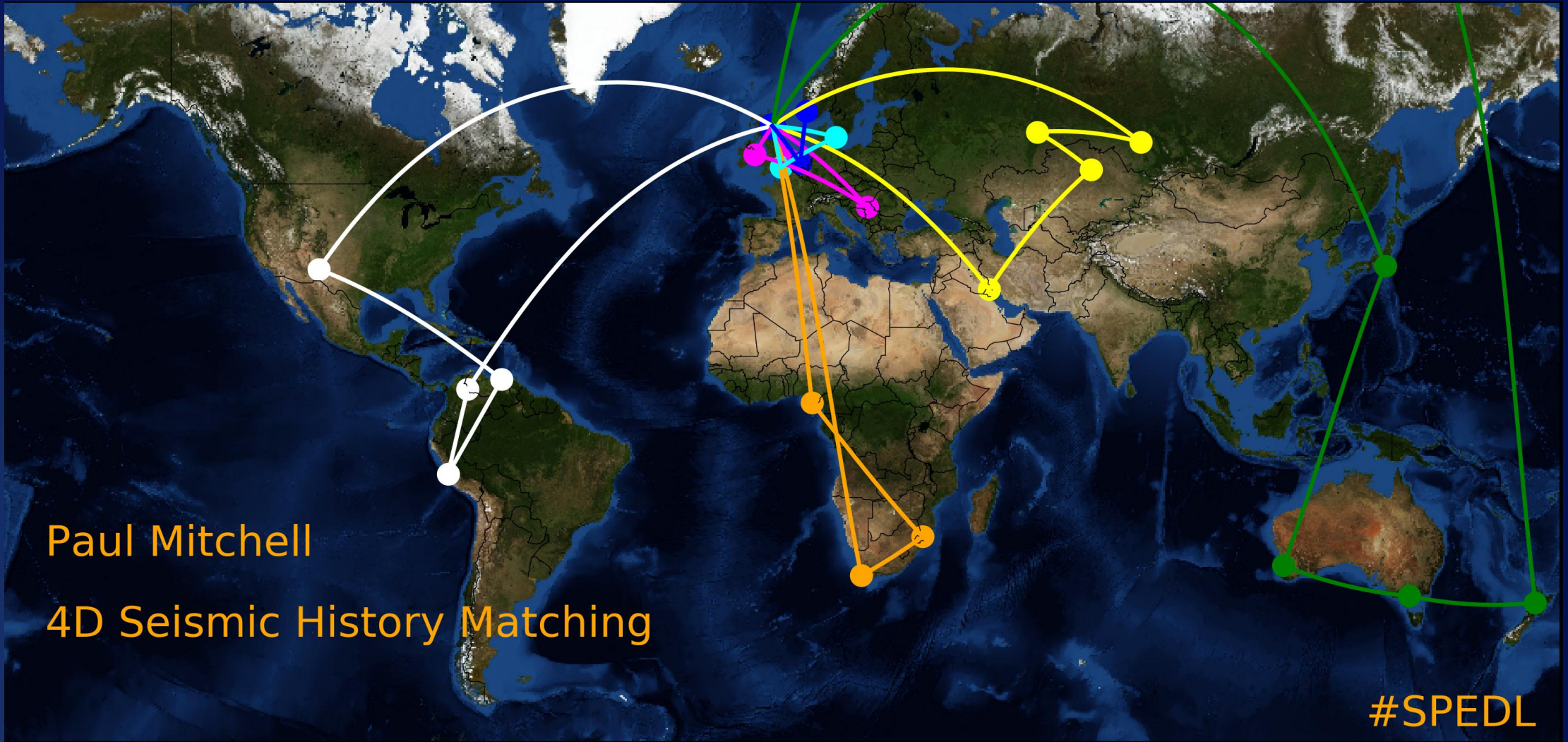
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4D Seismic History Matching

Paul Mitchell
TAQA



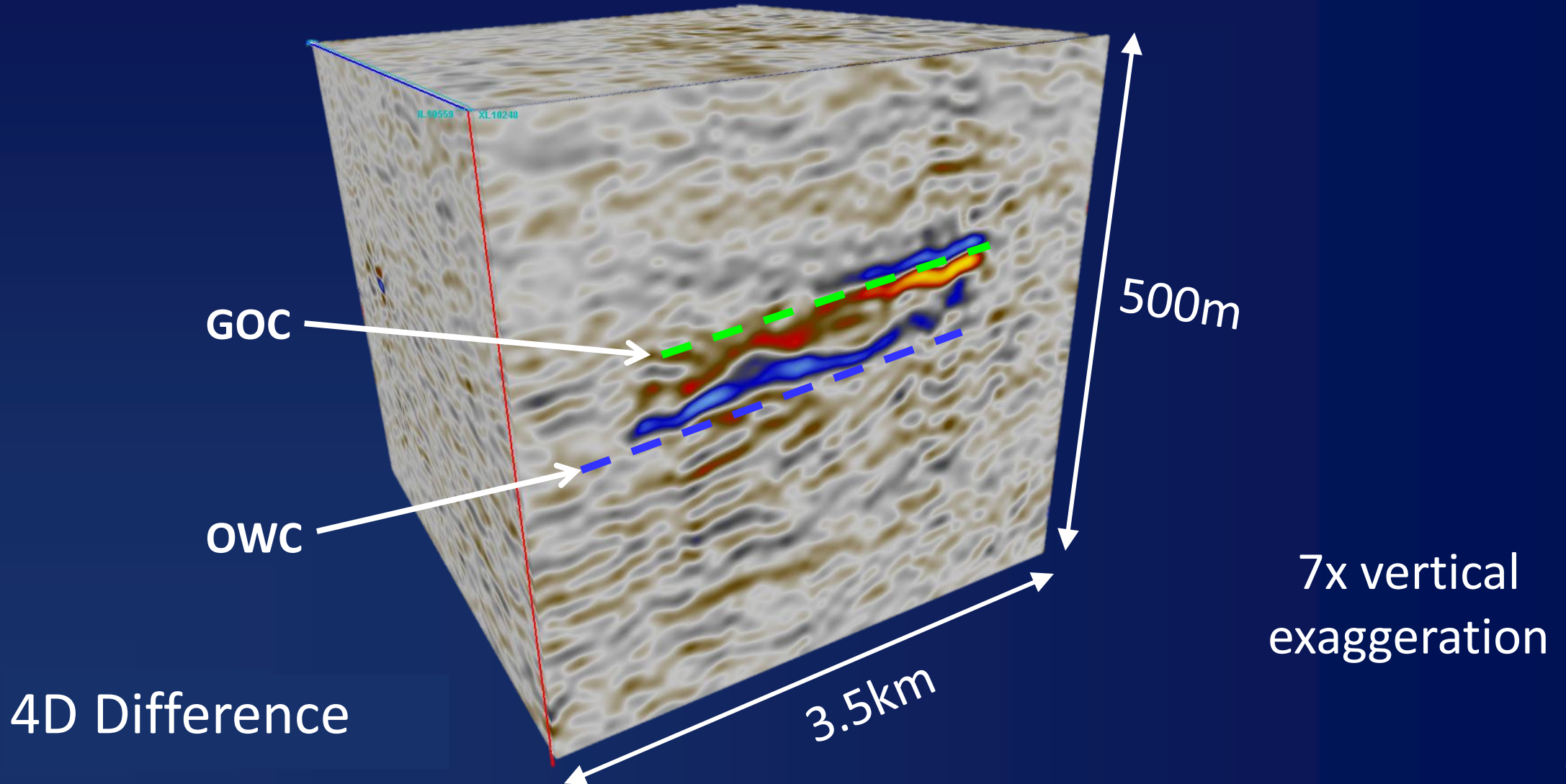
Society of Petroleum Engineers
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Outline



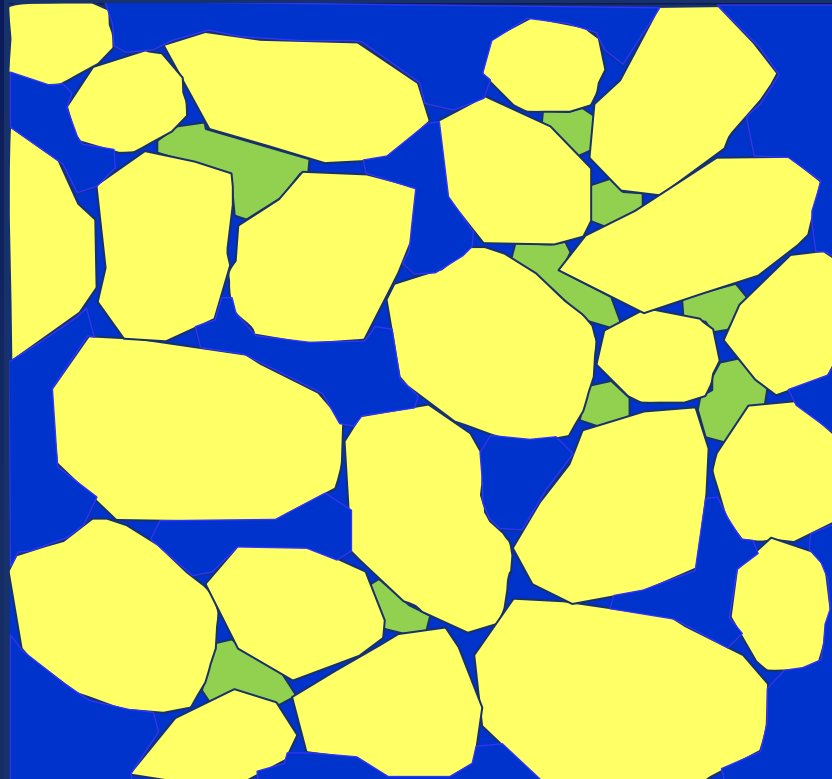
- Time-Lapse (4D) seismic
- 4D Seismic History Matching (4D SHM)
- The value of 4D SHM
- Harding & Gryphon case study
- 4D Assisted Seismic History Matching (4D ASHM)
- Future directions
- Conclusions

Introduction to Time-Lapse or 4D Seismic



How Does 4D Work? Water Sweep...

Velocity ↑
Density ↑

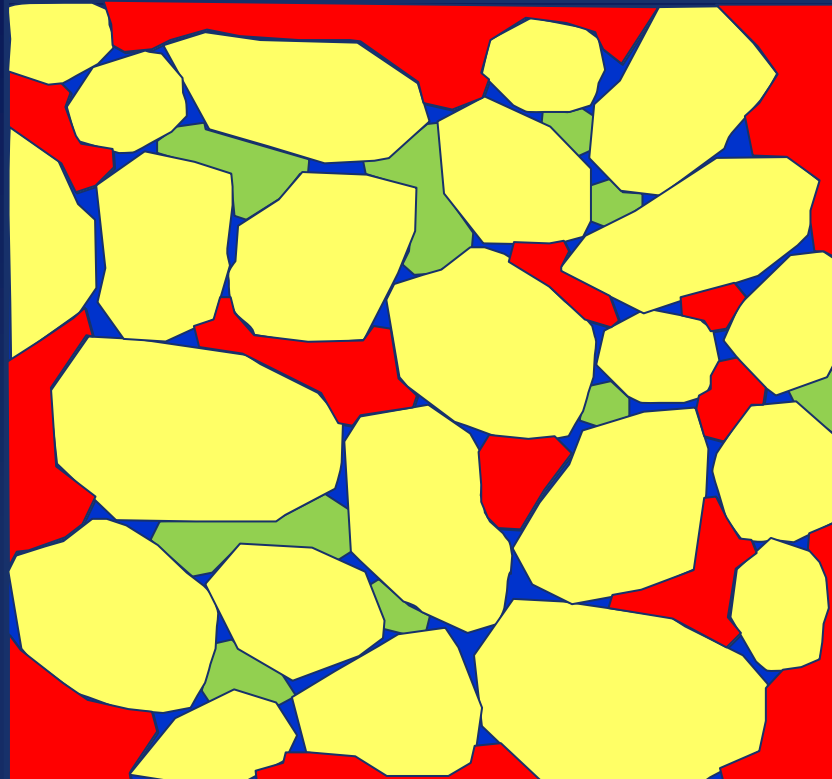



0 1mm



How Does 4D Work? Gas Sweep...

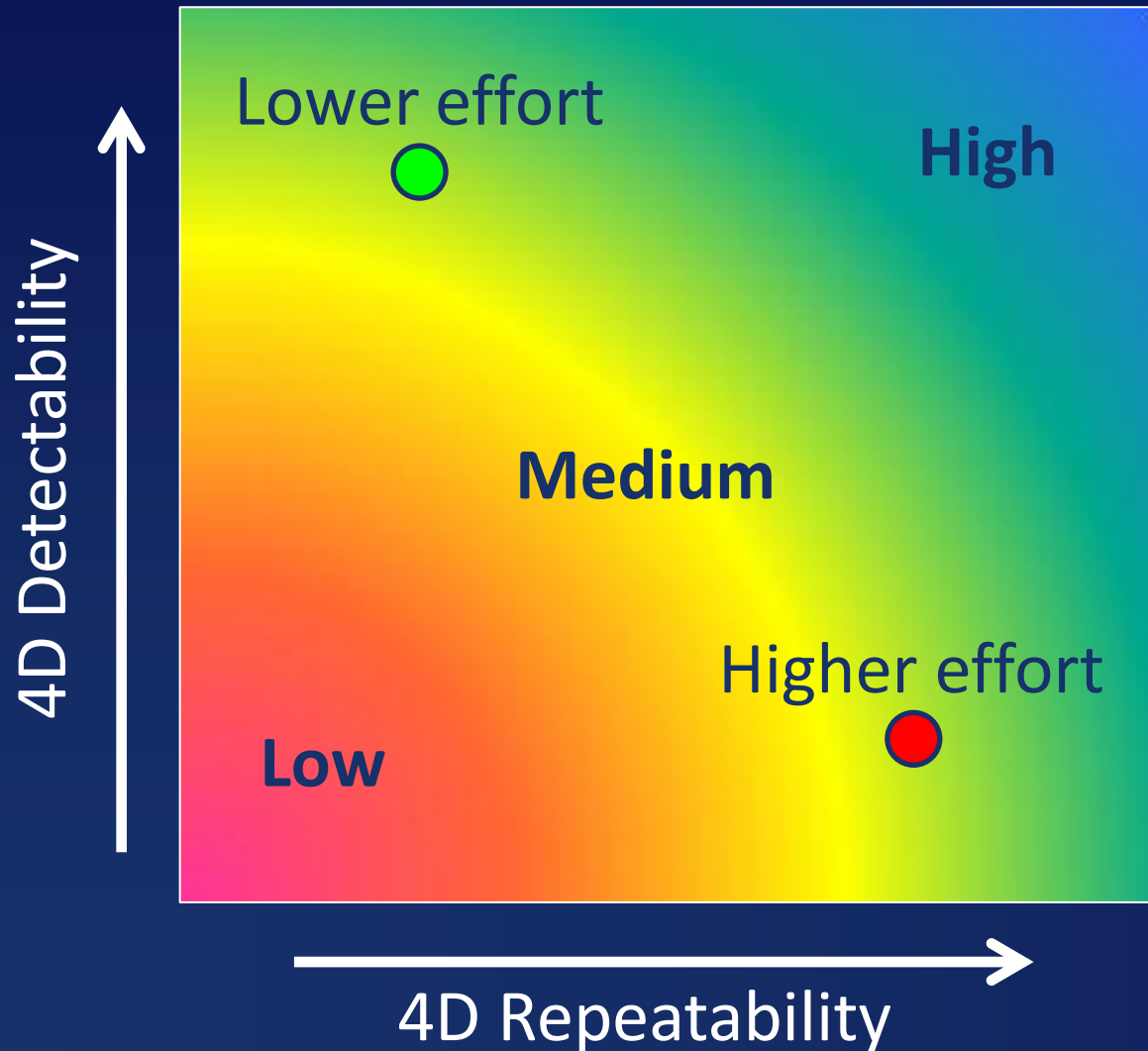
Velocity Density



0 1mm

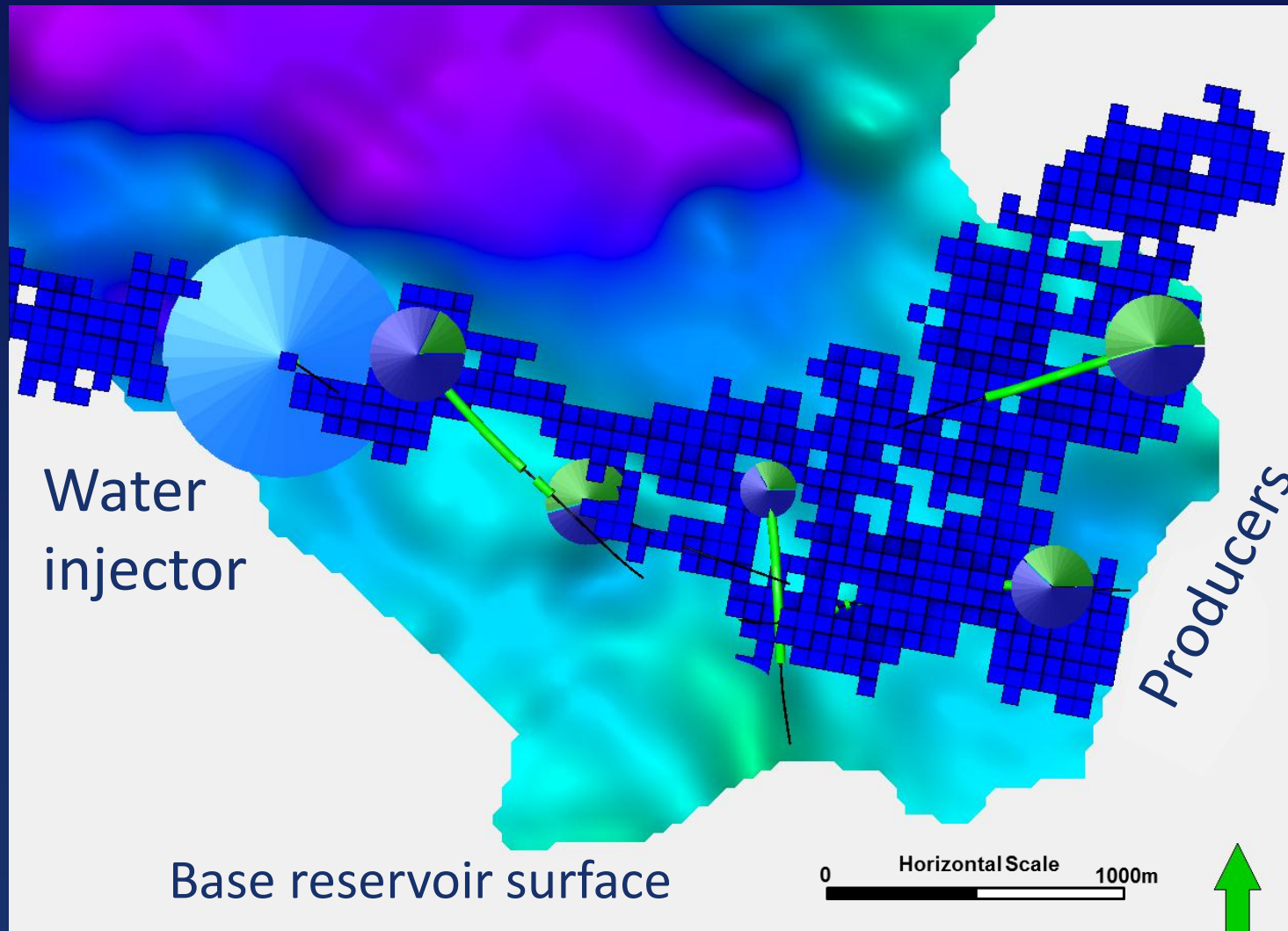


4D Chance of Success



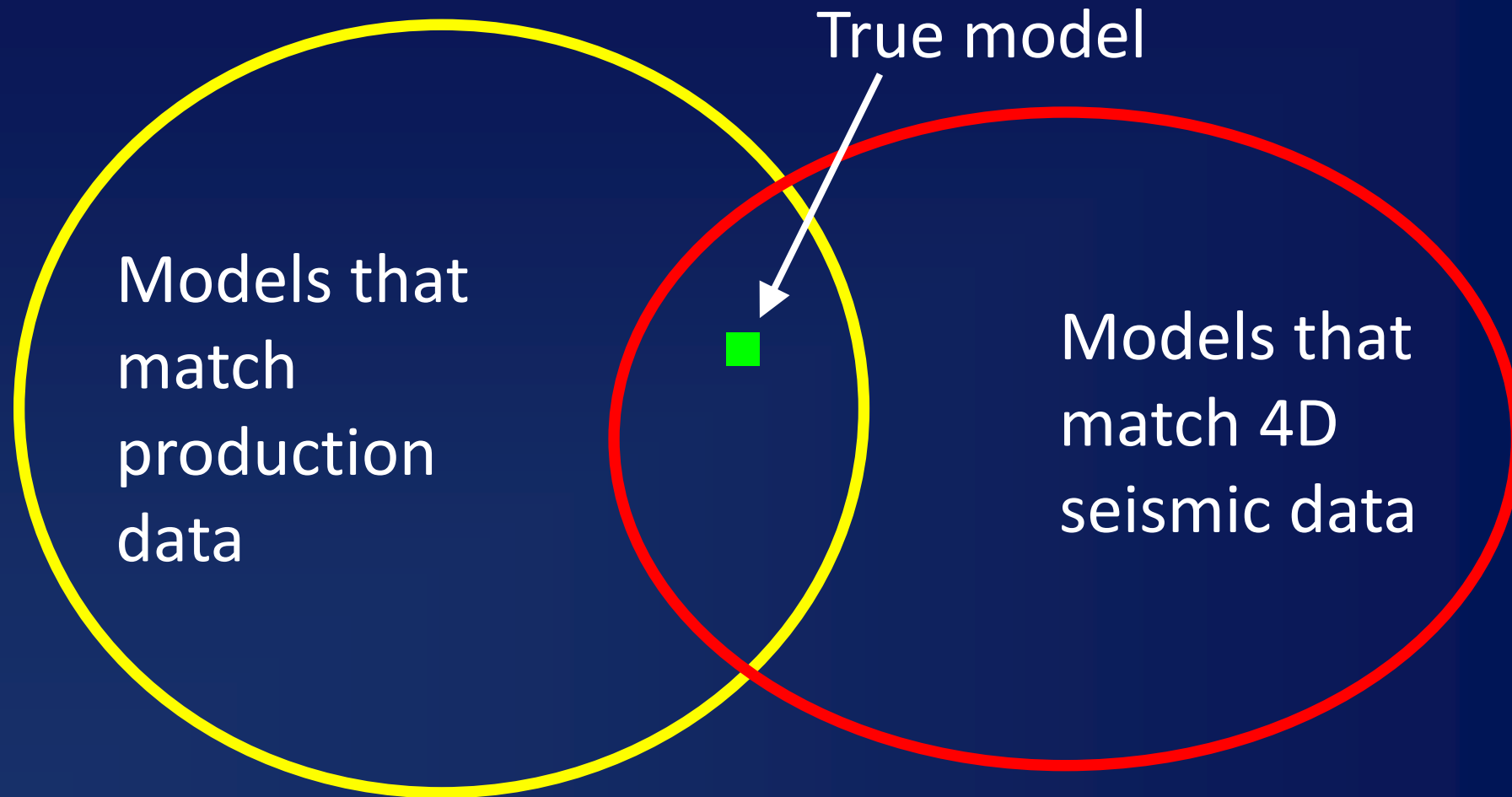
- 4D Detectability
 - Rock & fluid properties
 - Depletion process
 - Resolution
- 4D Repeatability
 - Acquisition geometry
 - Processing
 - Overburden complexity
 - Signal-to-noise

Reservoir Monitoring with 4D Seismic



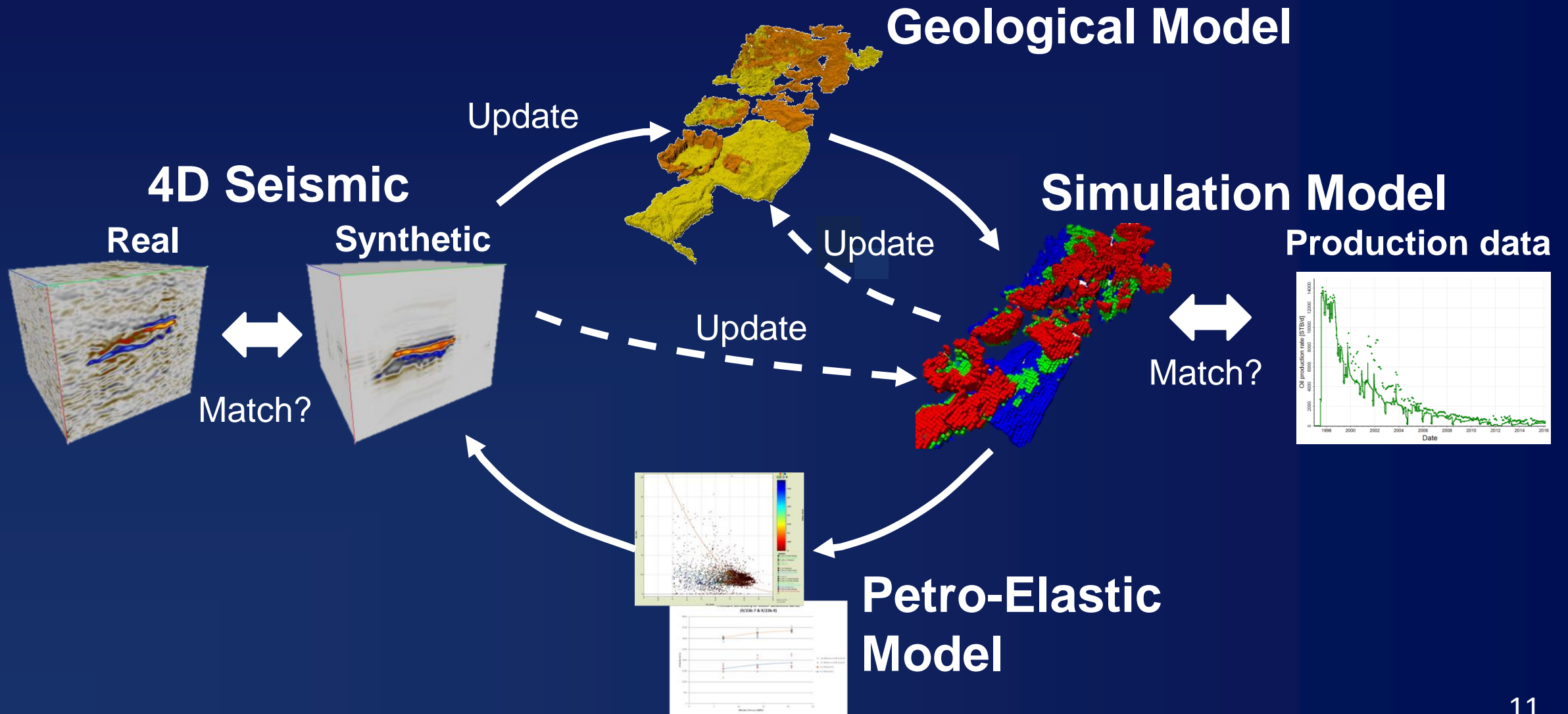
- Production data
 - temporally dense
 - spatially sparse
- 4D seismic data
 - spatially extensive
 - temporally sparse
- Complementary

Principle of 4D Seismic History Matching



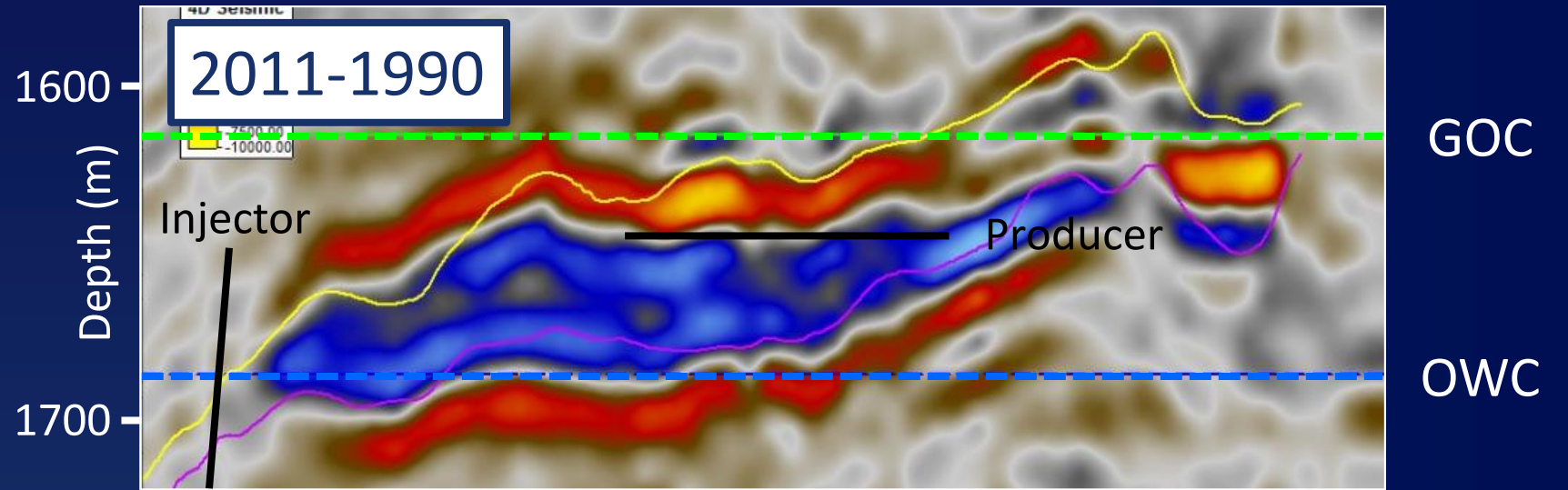
4D seismic history matching using information from the flooded zone, Jin, L., et al., 2012.

4D Seismic History Matching Workflow

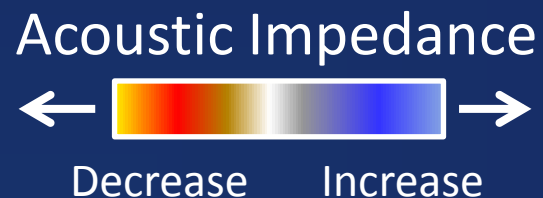
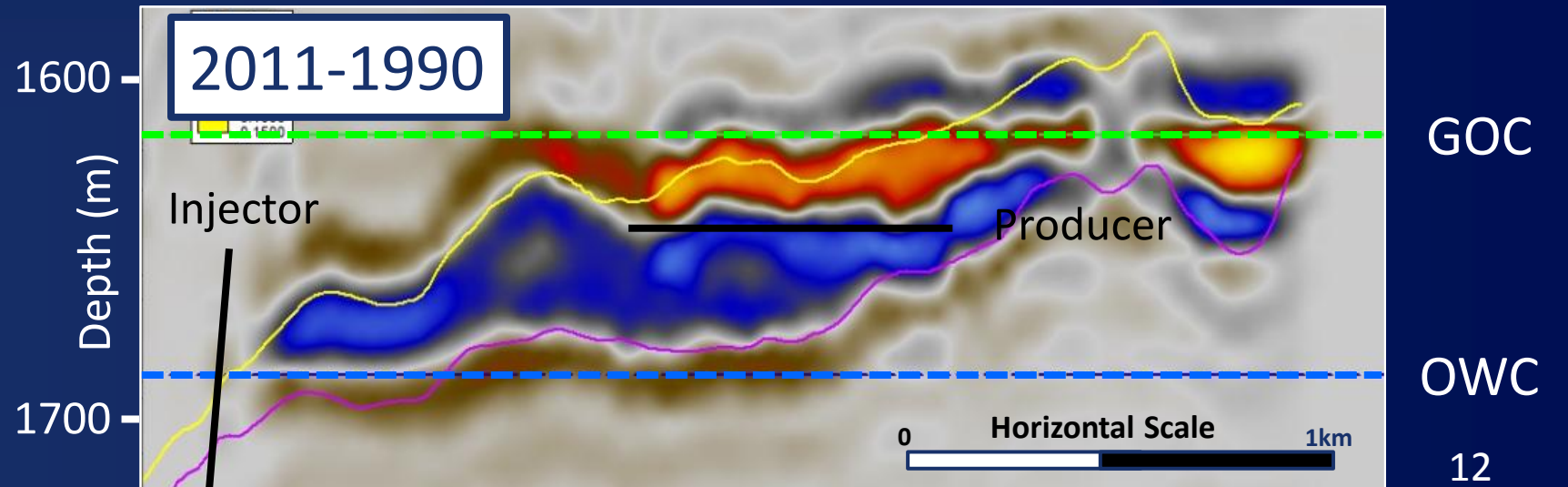


Seismic History Matching Example

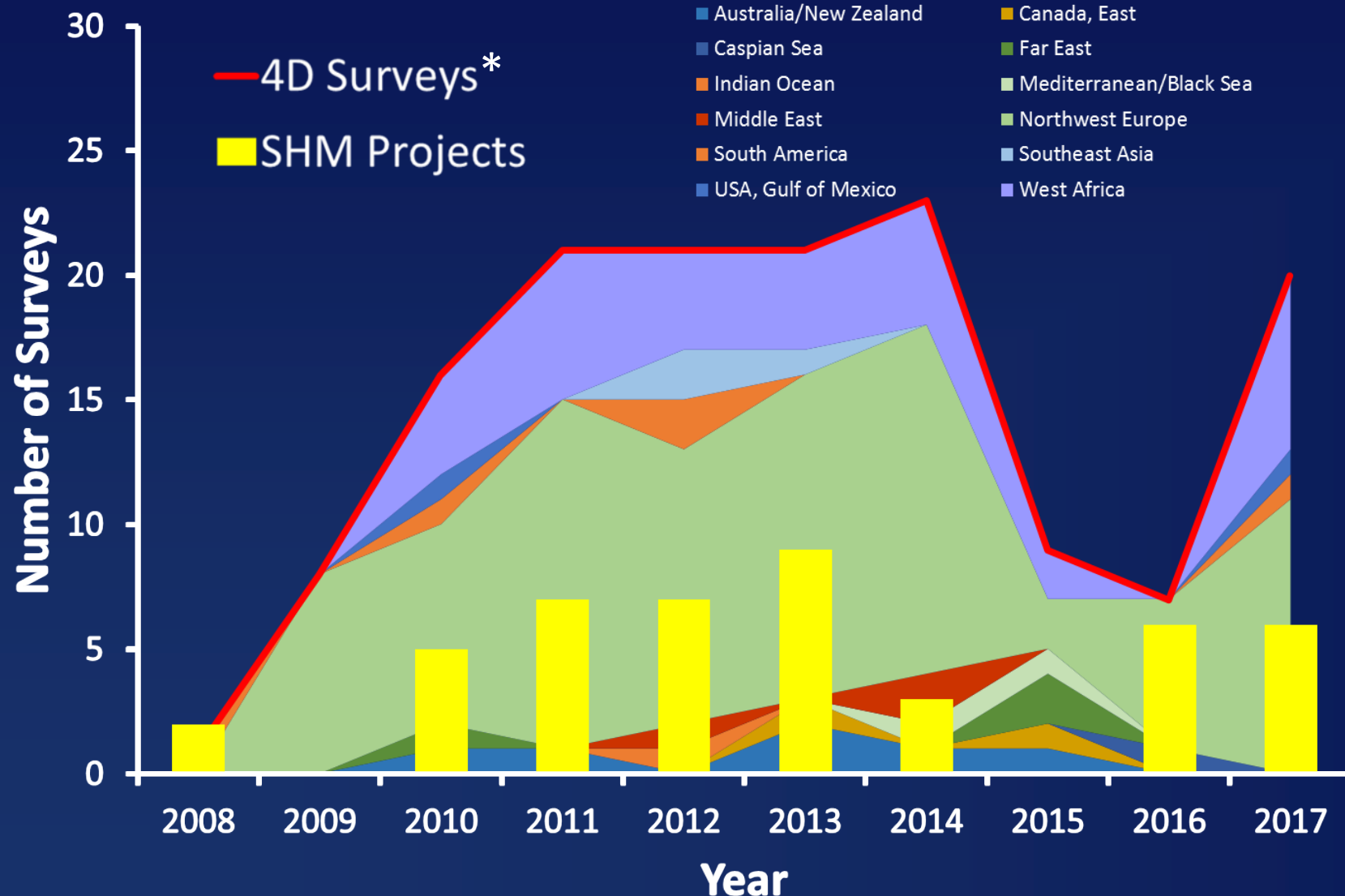
Real 4D Seismic



Synthetic 4D Seismic



The Value of 4D SHM

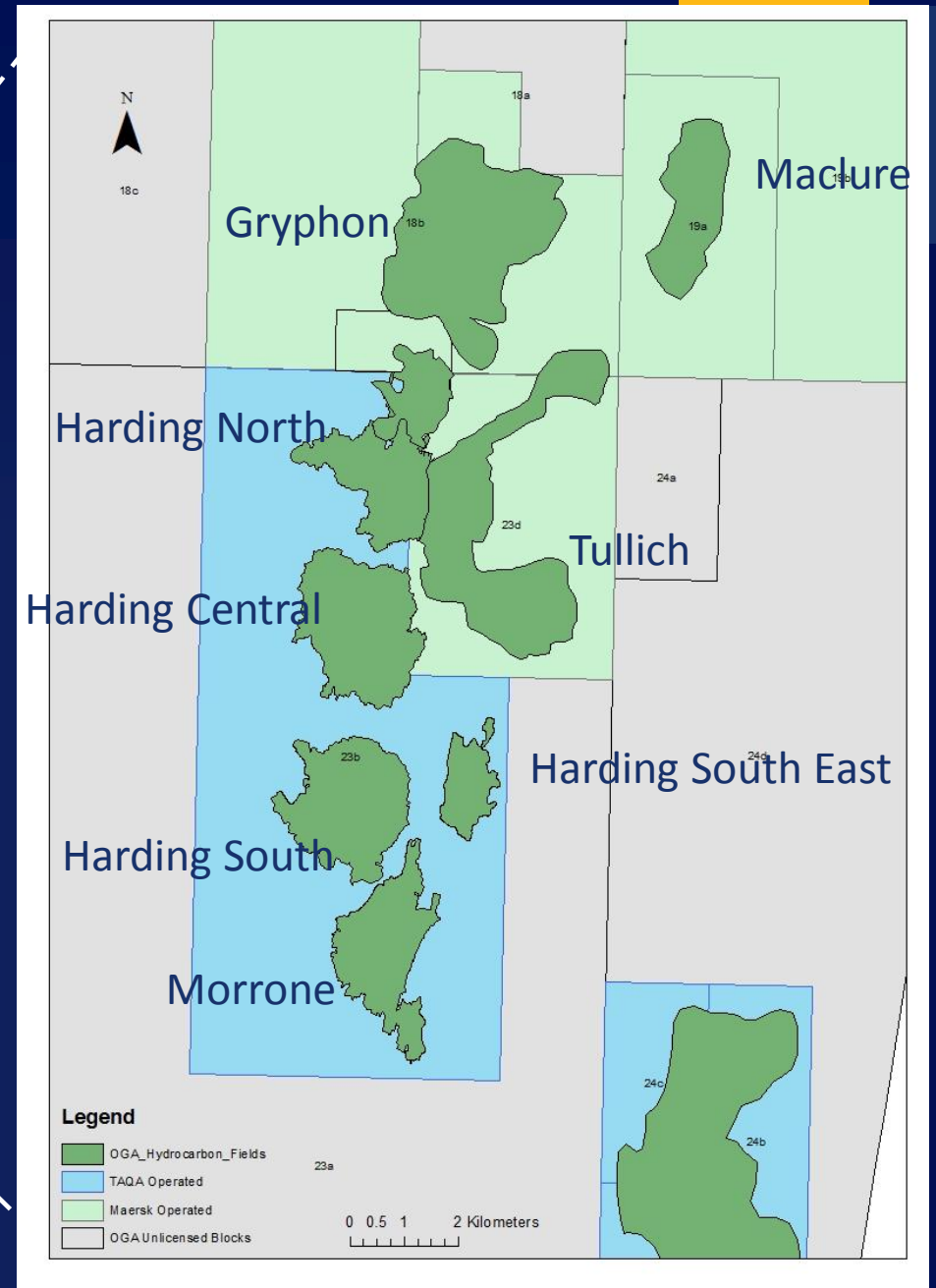


- \$1-2bn annual spend on 4D seismic globally
- Greater value can be extracted from the data

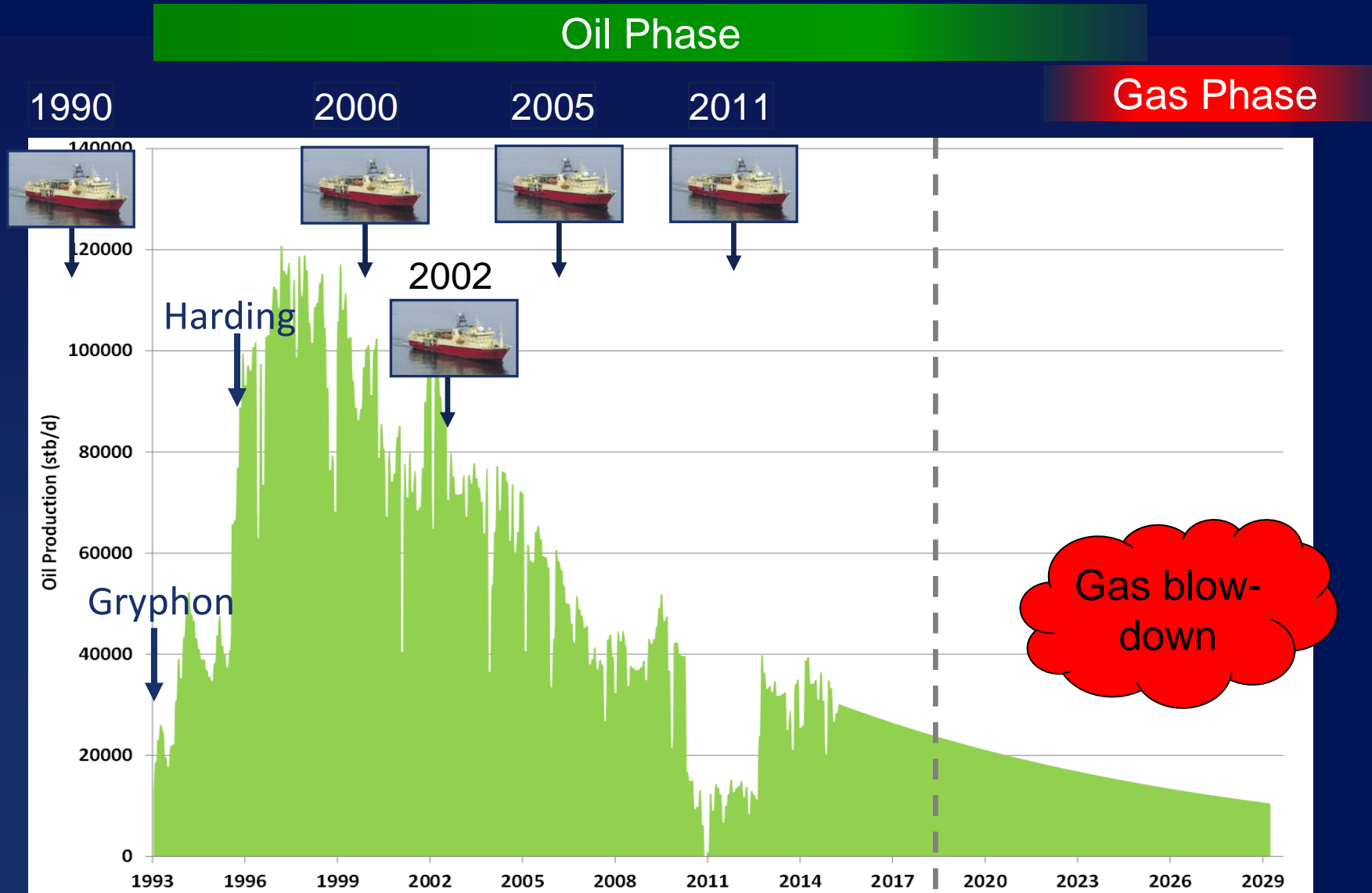
* Source: SeismicBase by IHS Markit

Harding & Gryphon Fields

- North Sea
 - 320km NE Aberdeen
- TAQA and Total operated fields
- Oil production
 - Gas caps remain
- Morrone undeveloped

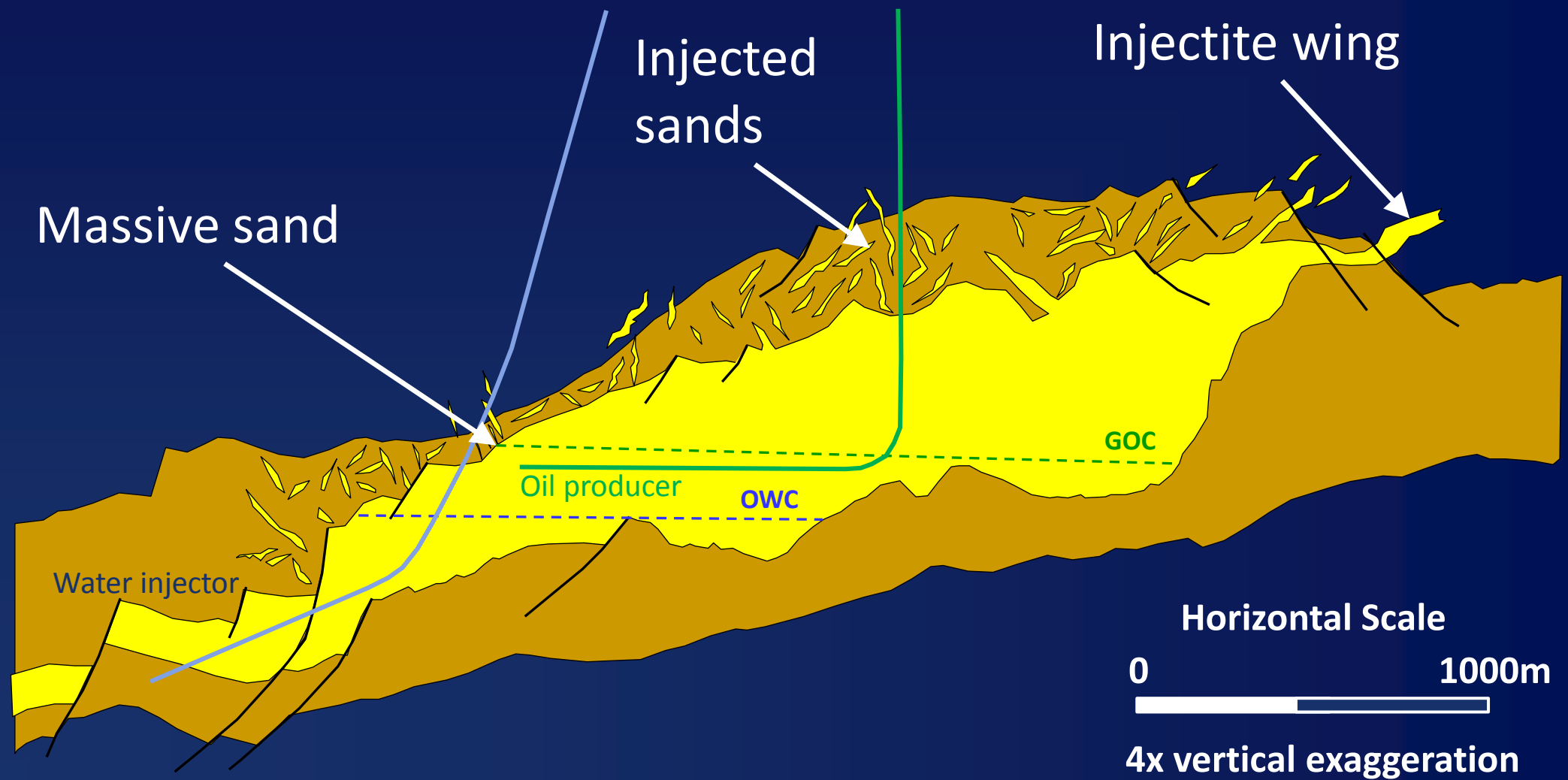


Production & Seismic History





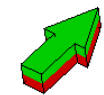
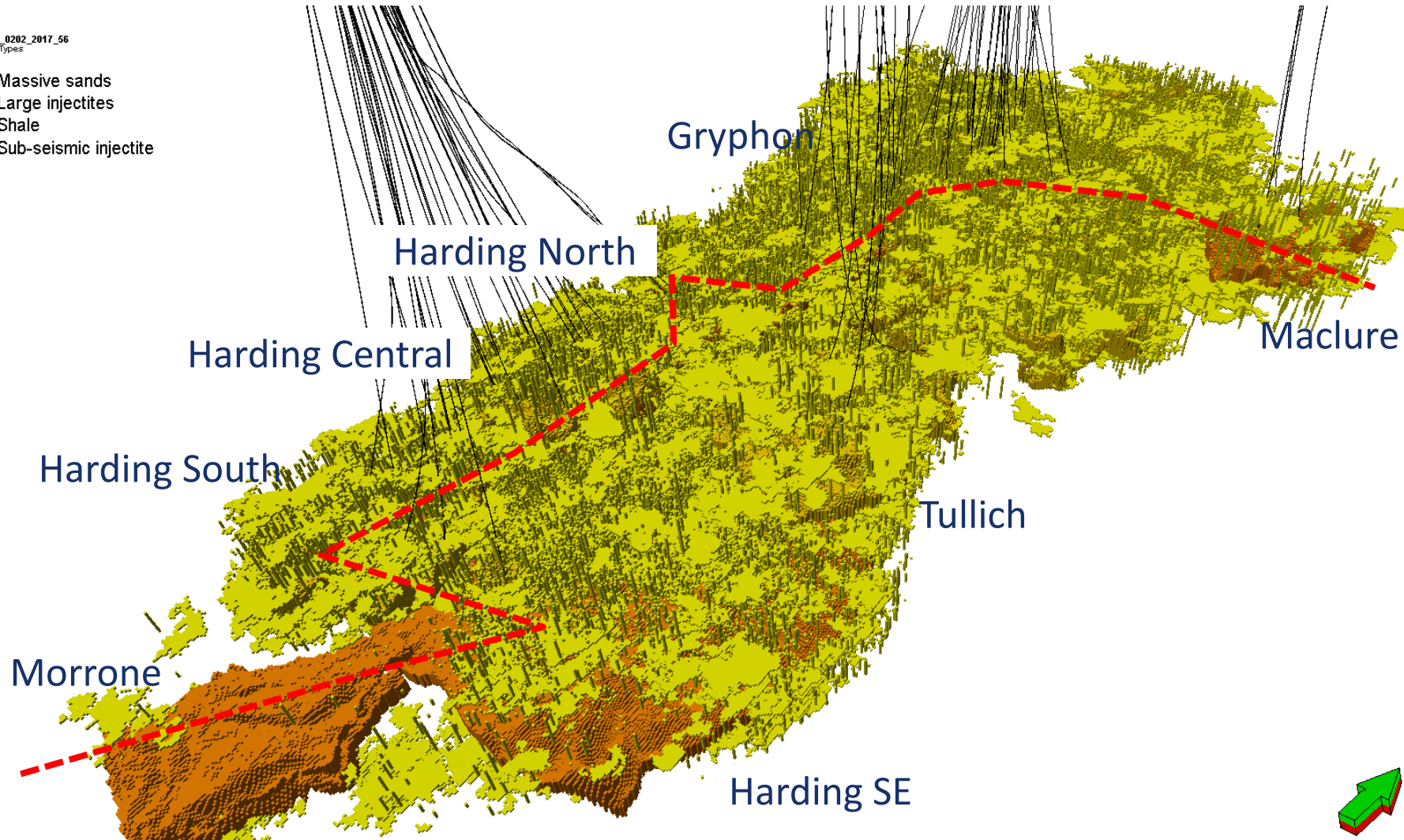
Geology



Geological and Simulation Models

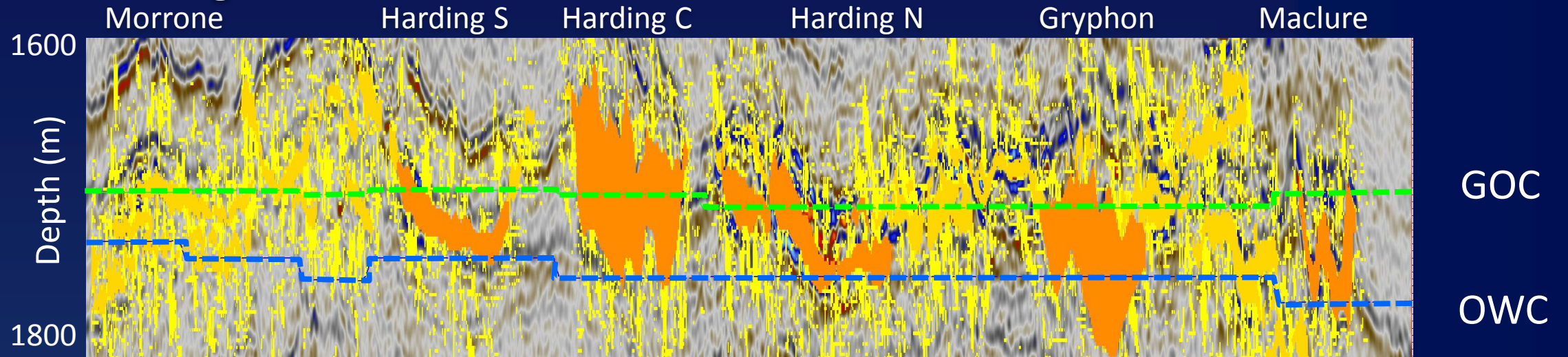
Geobodies_0202_2017_56
GBD Sands Types

- Massive sands
- Large injectites
- Shale
- Sub-seismic injectite

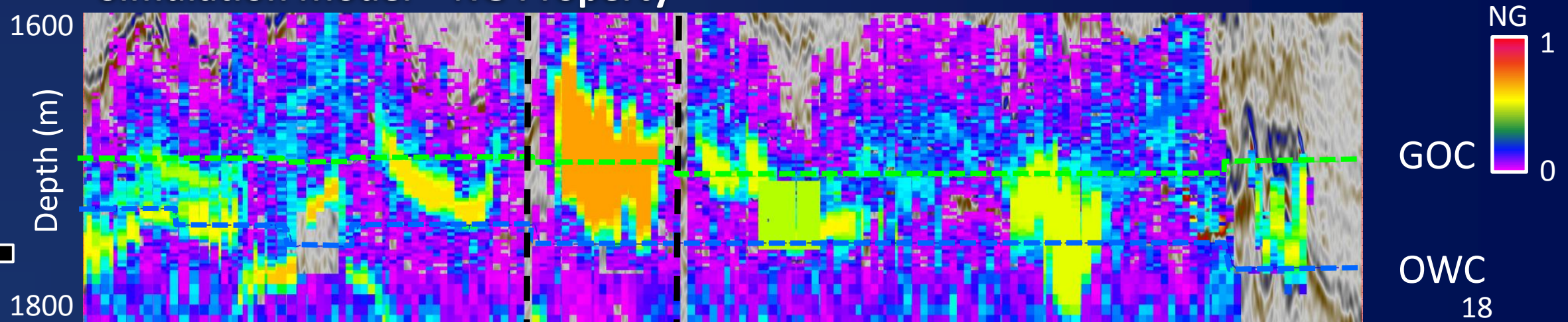


Initial Models

Geological Model - Facies

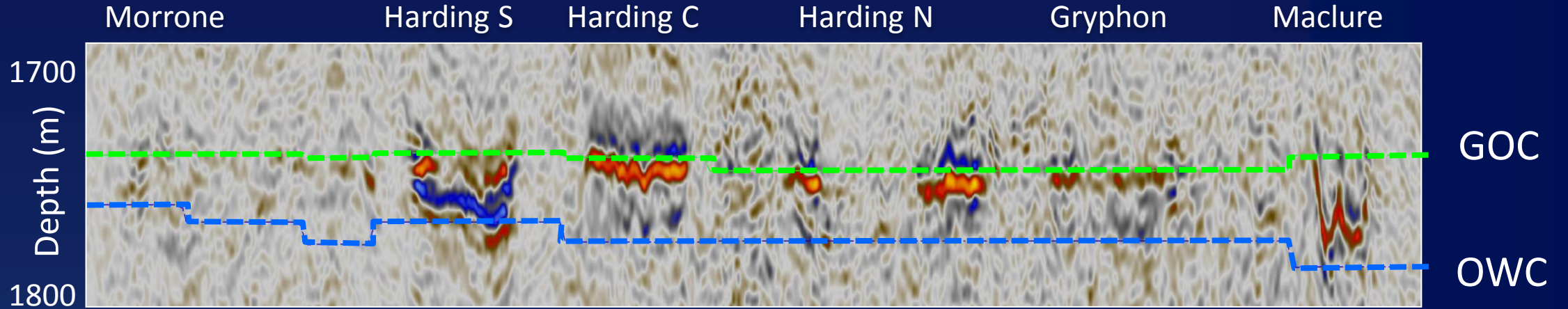


Simulation Model – NG Property

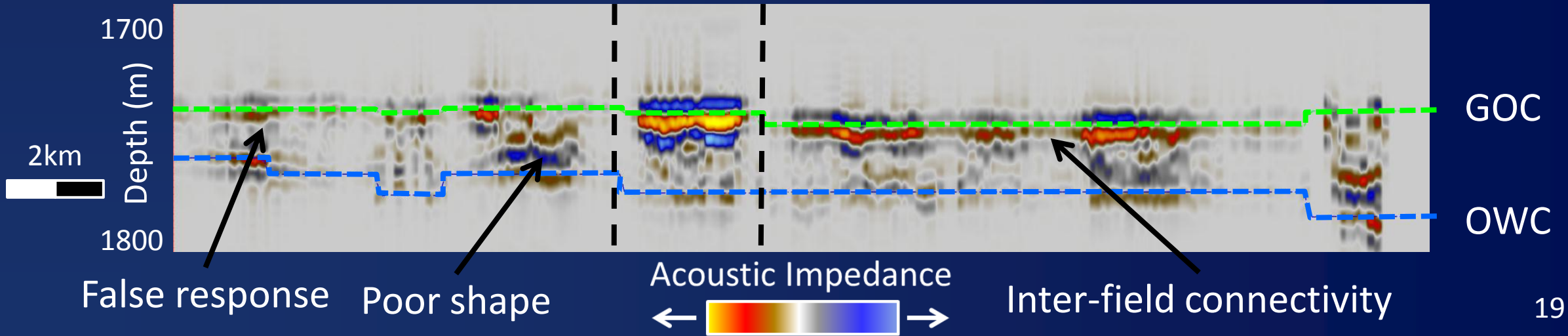


Initial Model 4D Seismic

Real 4D Seismic Difference



Model 4D Seismic Difference

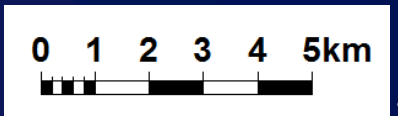
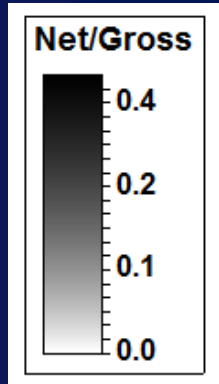
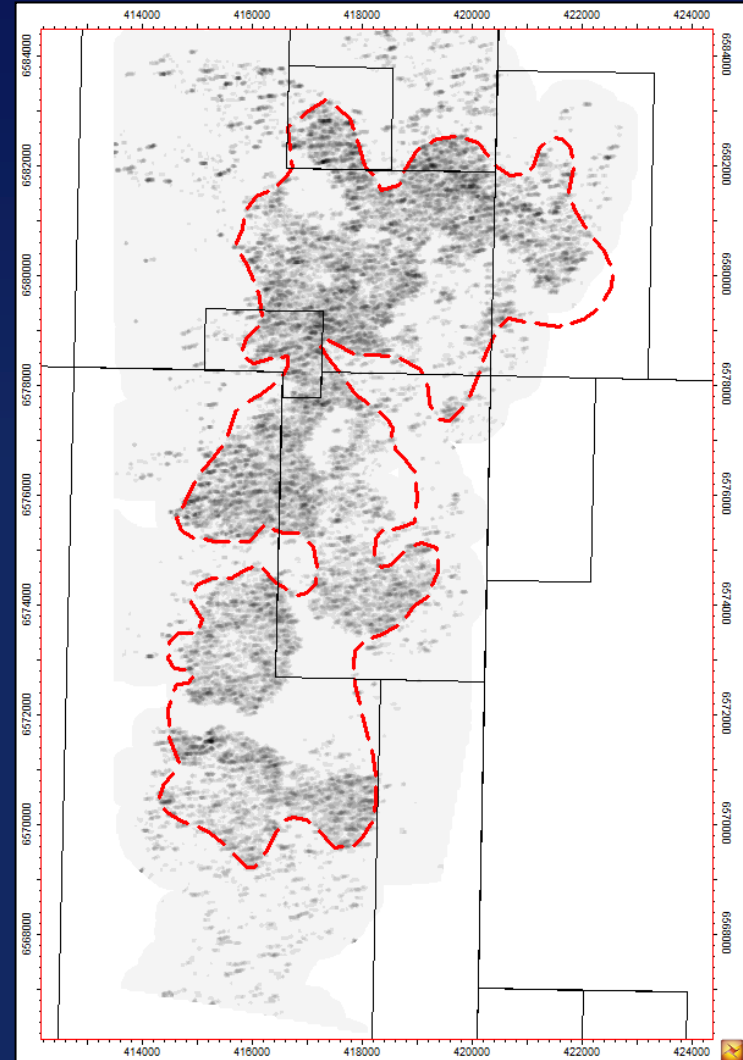
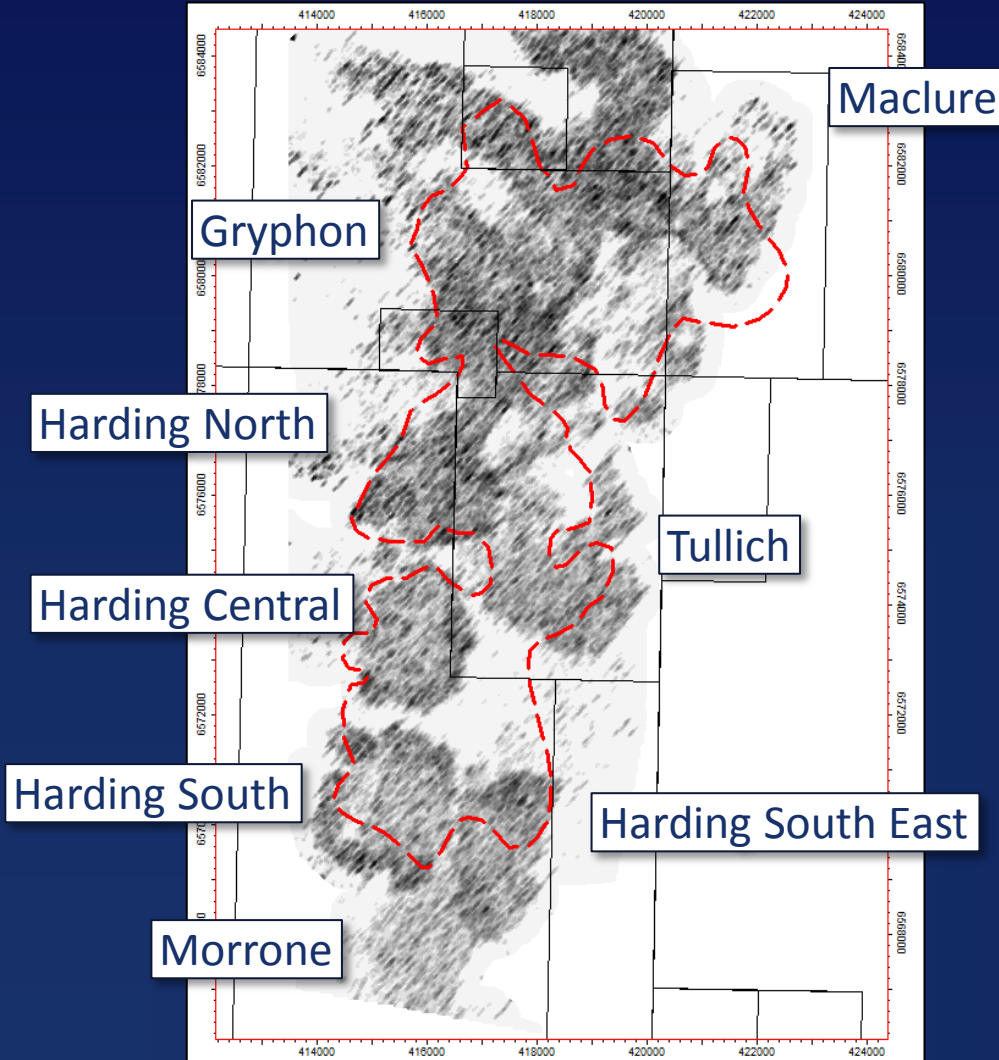




Redistribution of Sand Injectites

Initial Injectite Density

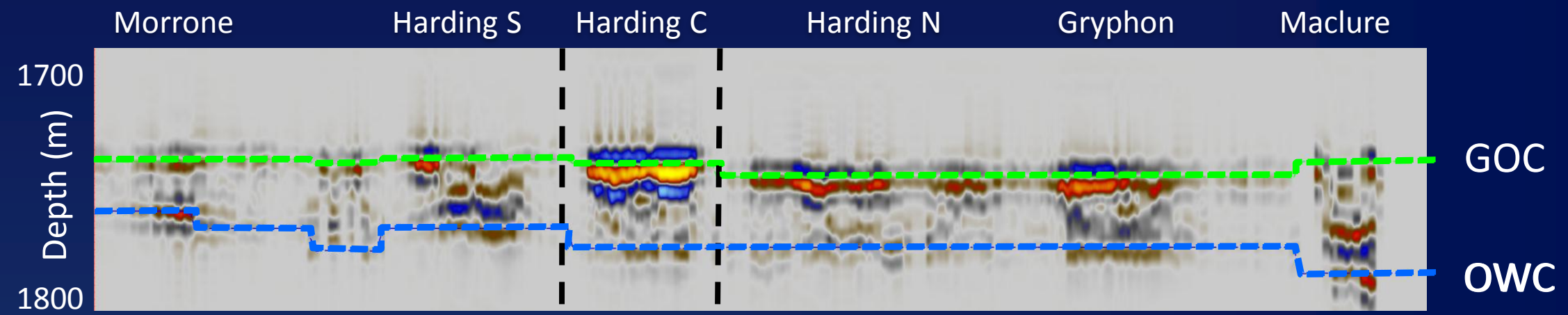
Updated Injectite Density



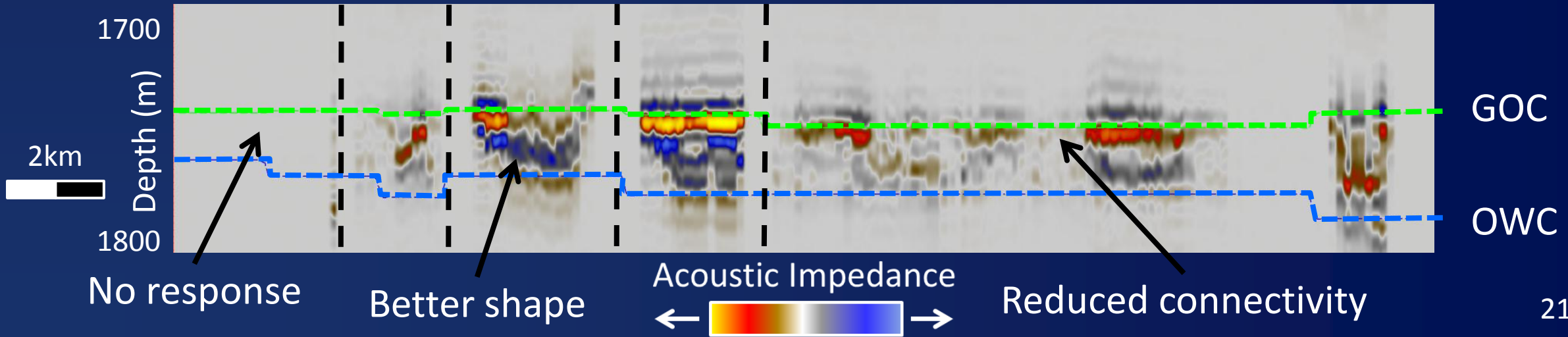


Updated Model 4D Seismic

Initial Model 4D Seismic Difference

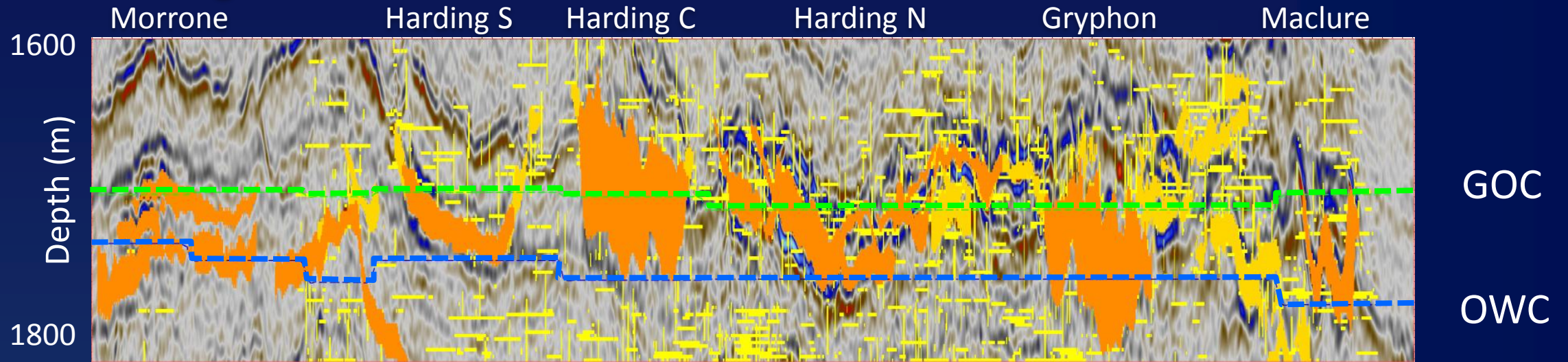


Updated Model 4D Seismic Difference

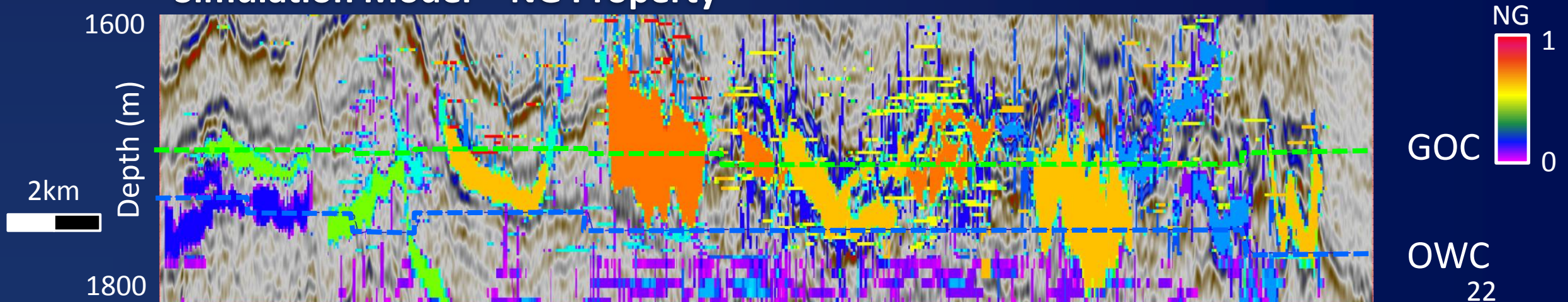


Fine-Scale Models

Geological Model - Facies

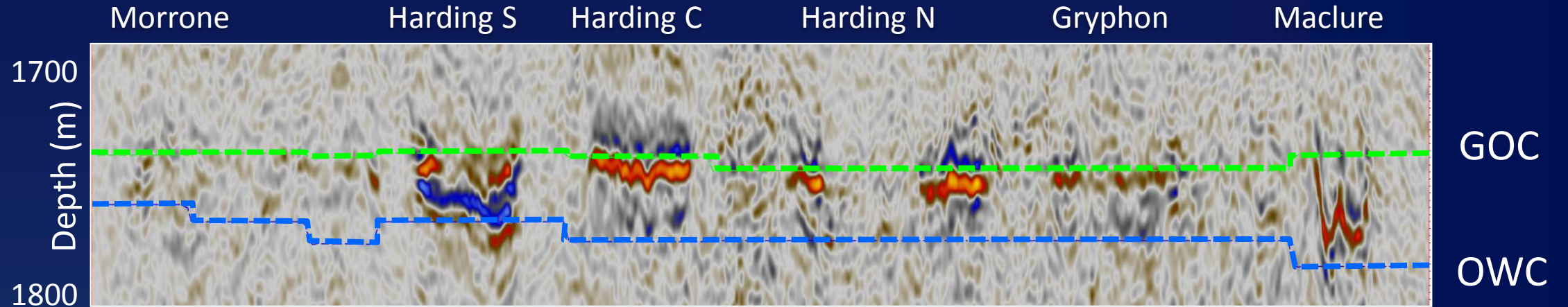


Simulation Model – NG Property

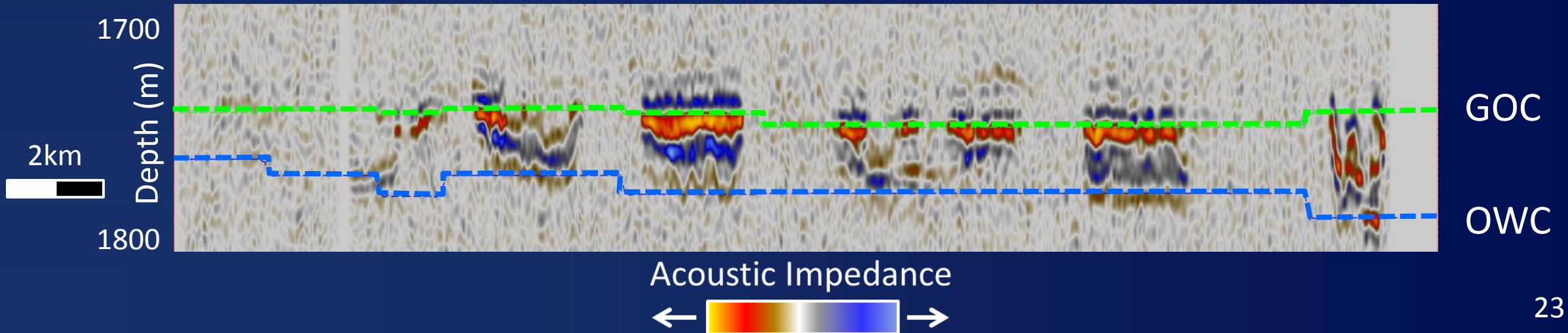


Fine-Scale Model 4D Seismic

Real 4D Seismic Difference

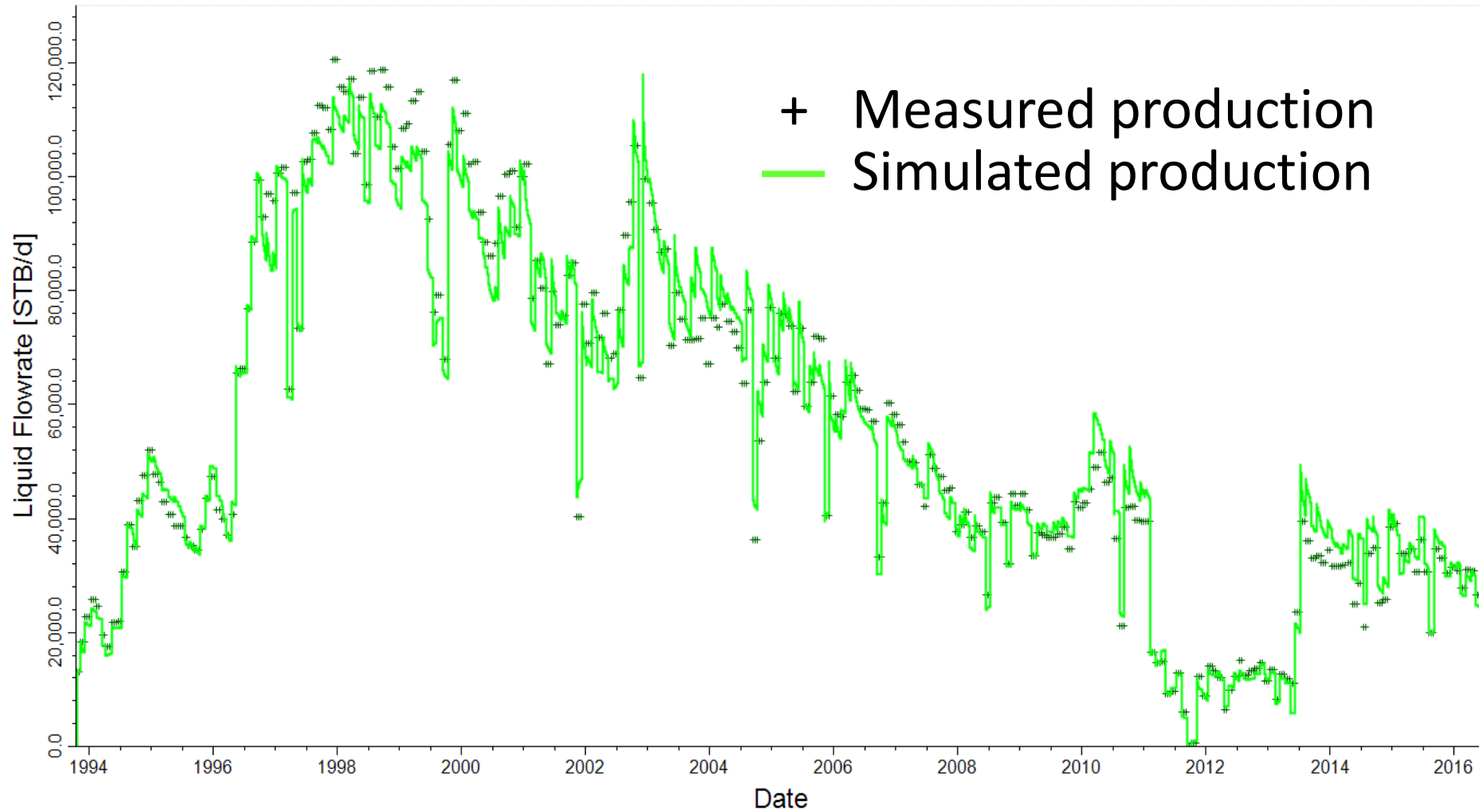


Model 4D Seismic Difference



Production History Match

Oil production (STB/d)



Pressure History Match



Seismic History Matching Summary

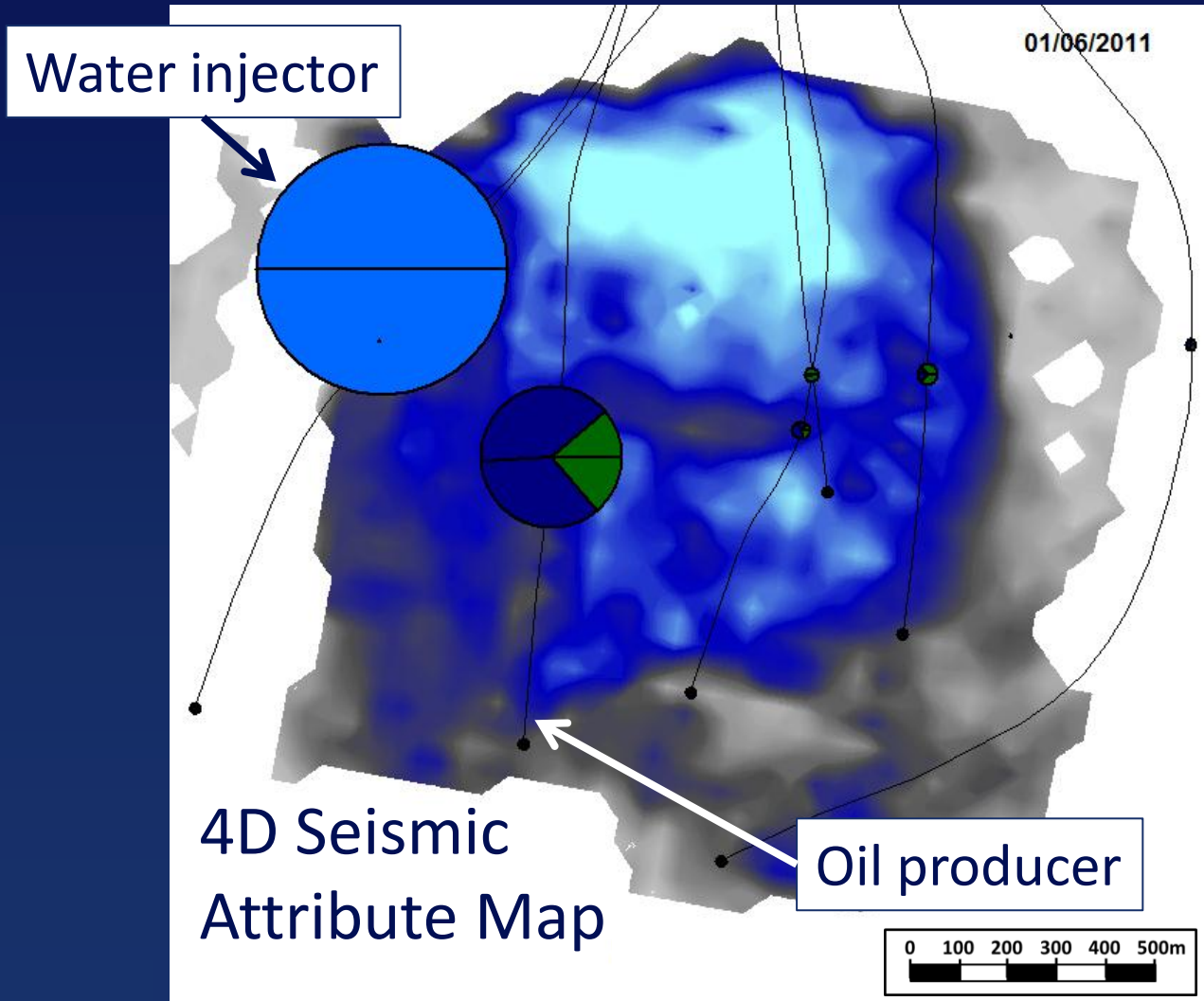
Model	Geological Description	History Match	4D Seismic Match
Initial model	●	●	●
Updated model	●	●	●
Fine-Scale model	●	●	●

● Poor

● Moderate

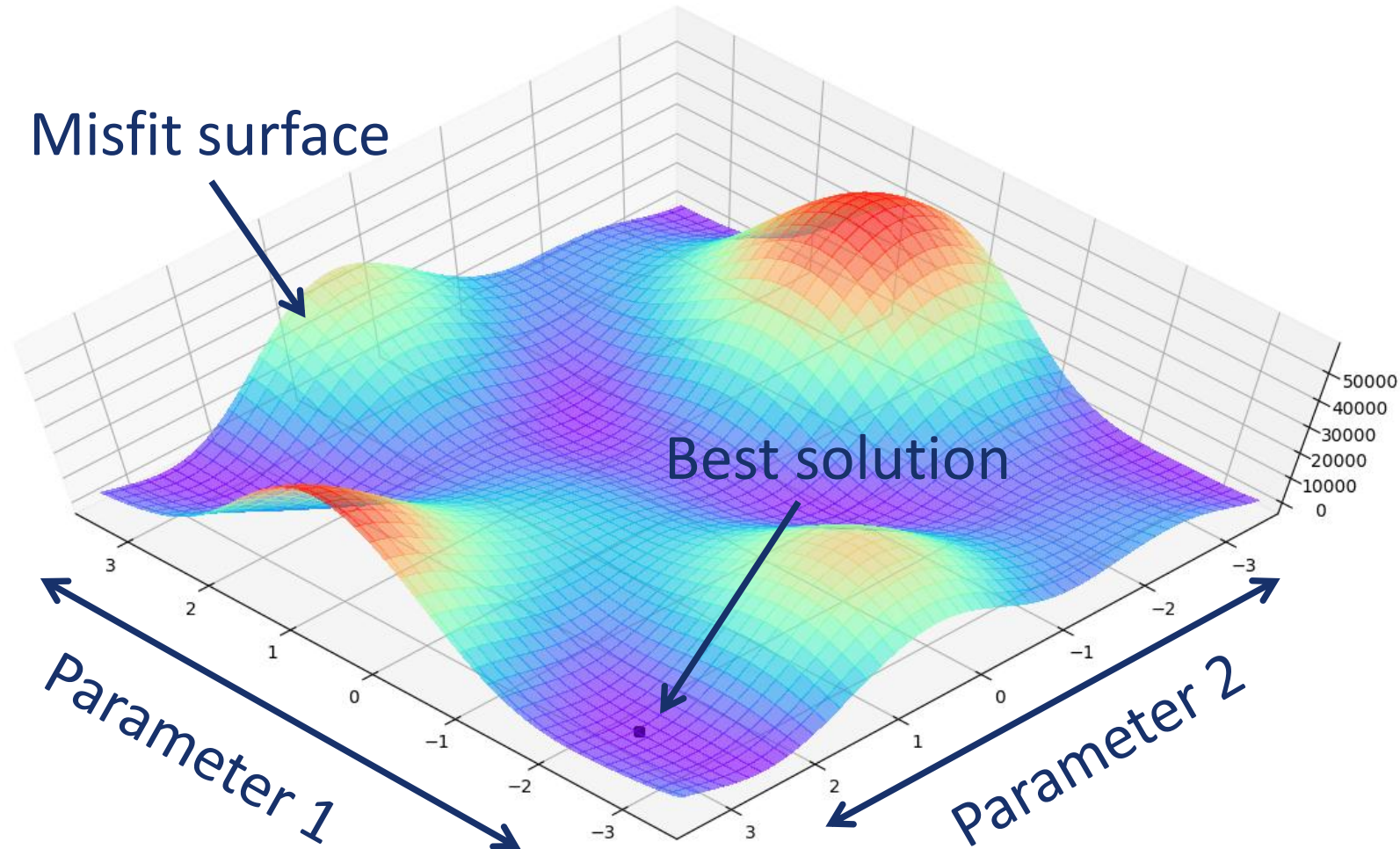
● Good

4D Assisted Seismic History Matching



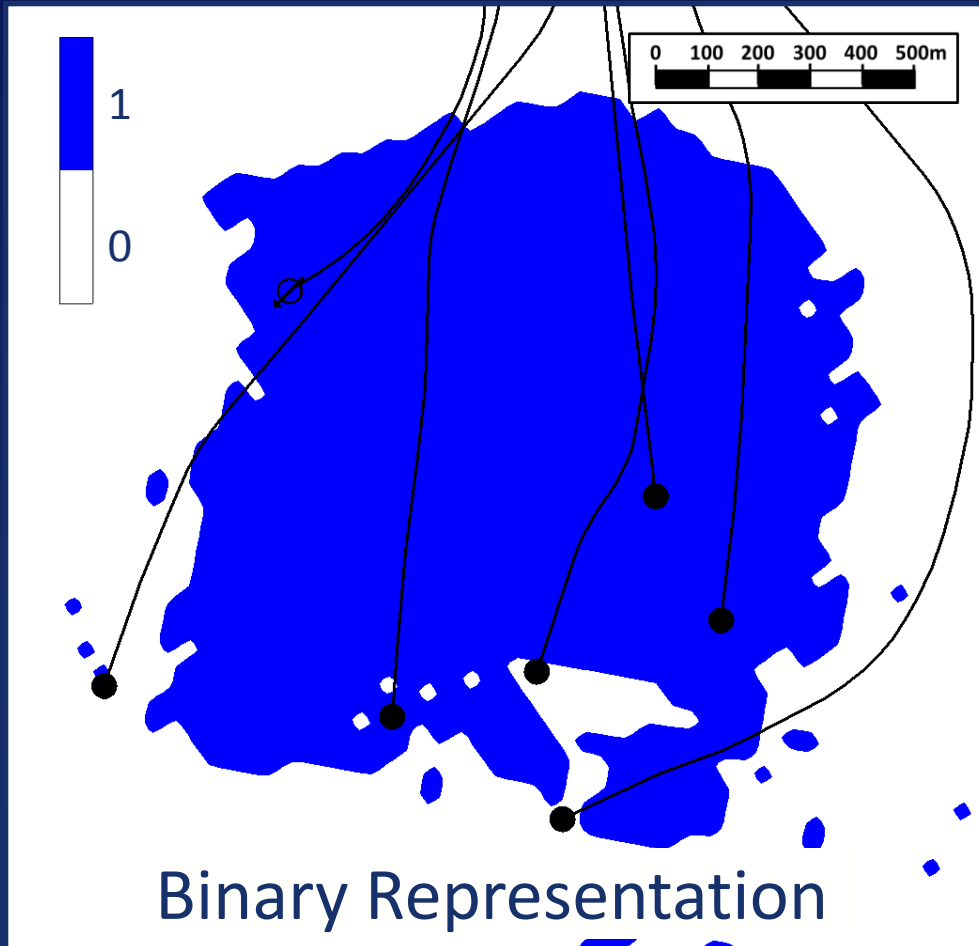
- Quantitative
- Automatic
- Intelligent

Genetic Algorithm for 4D ASHM

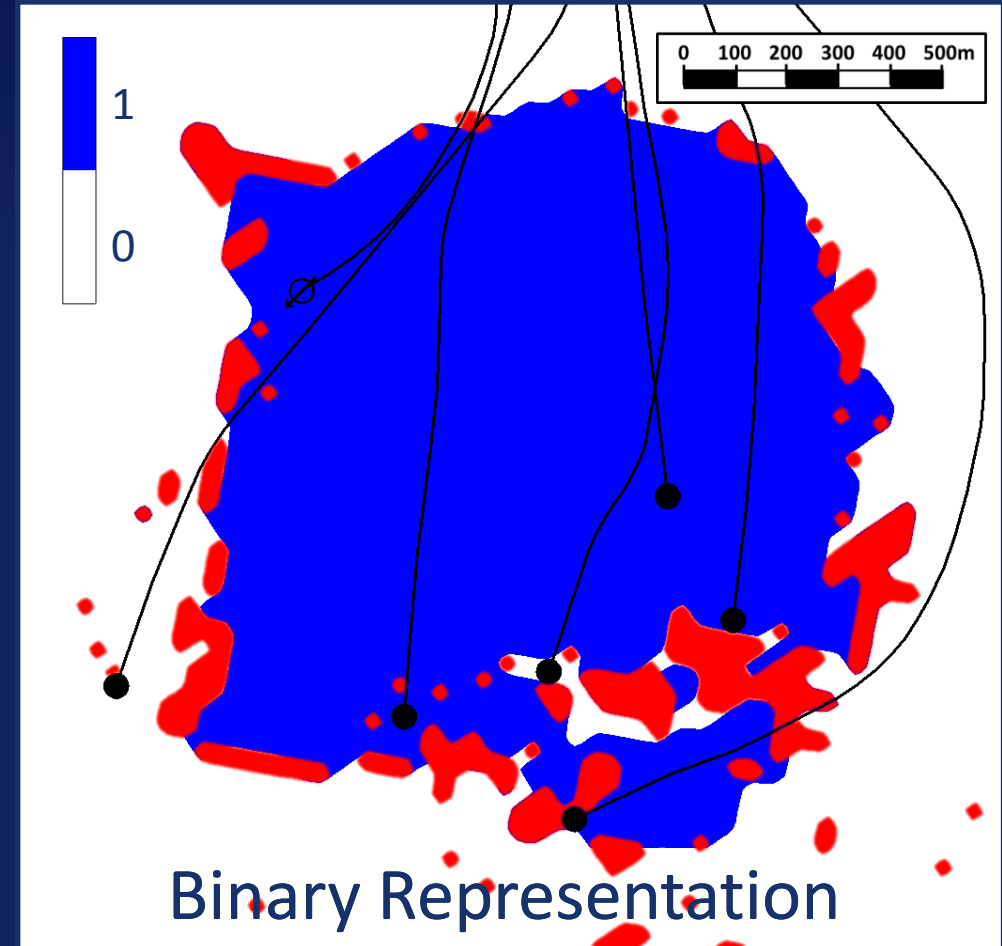


Quantitative 4D Analysis

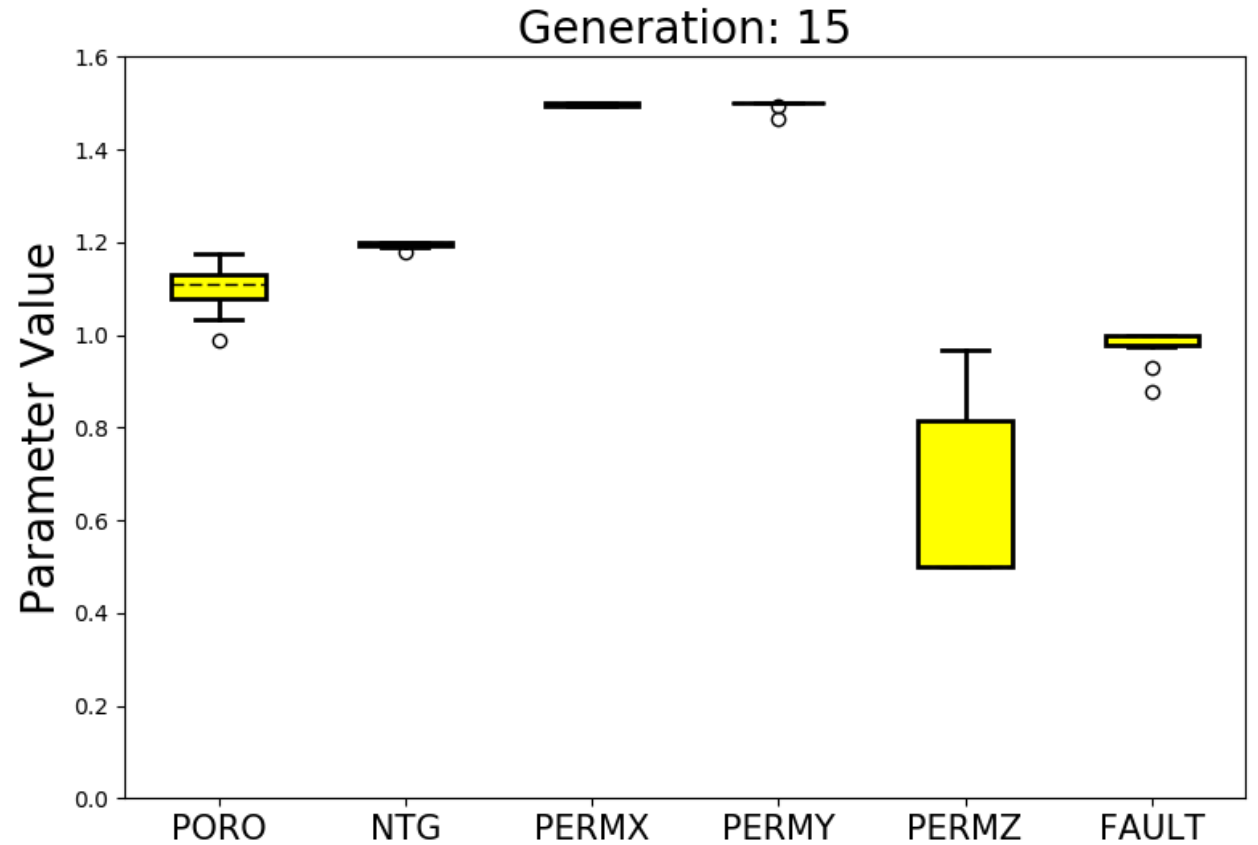
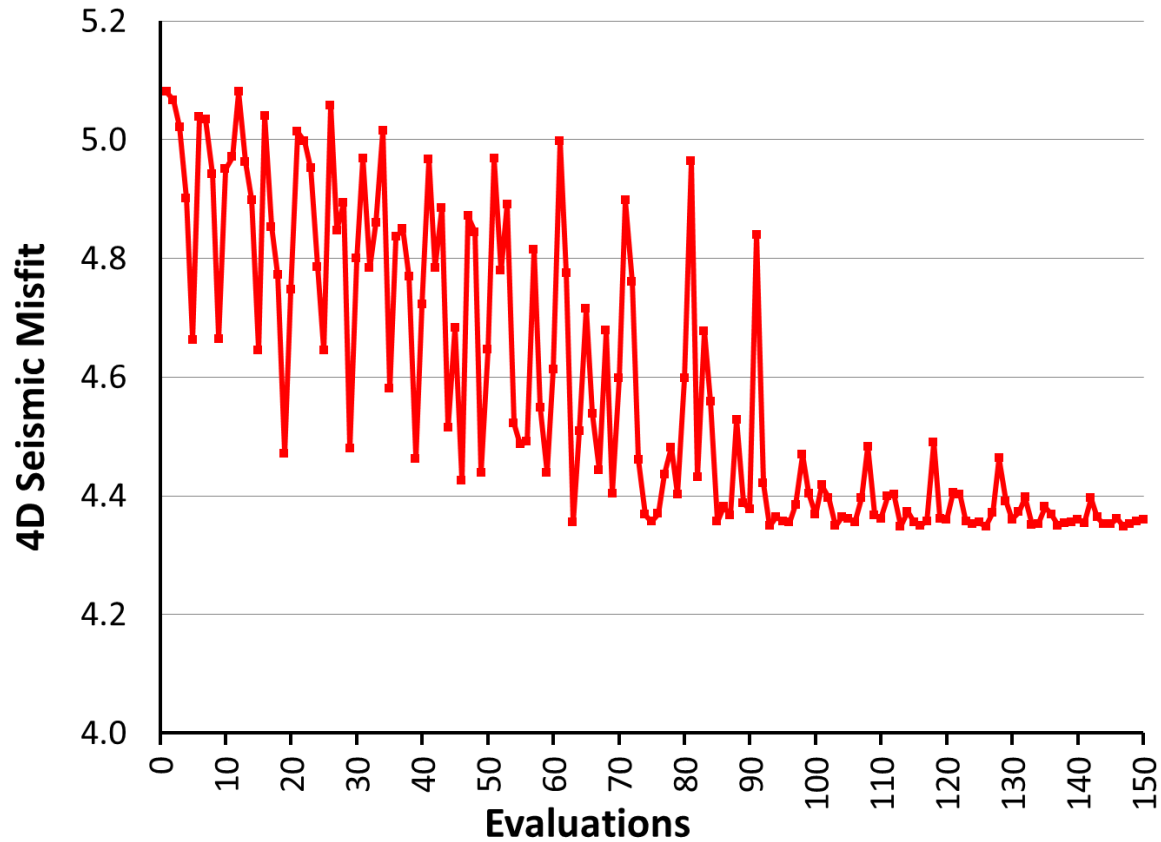
Real 4D Seismic Attribute Map



Model 4D Seismic Attribute Map

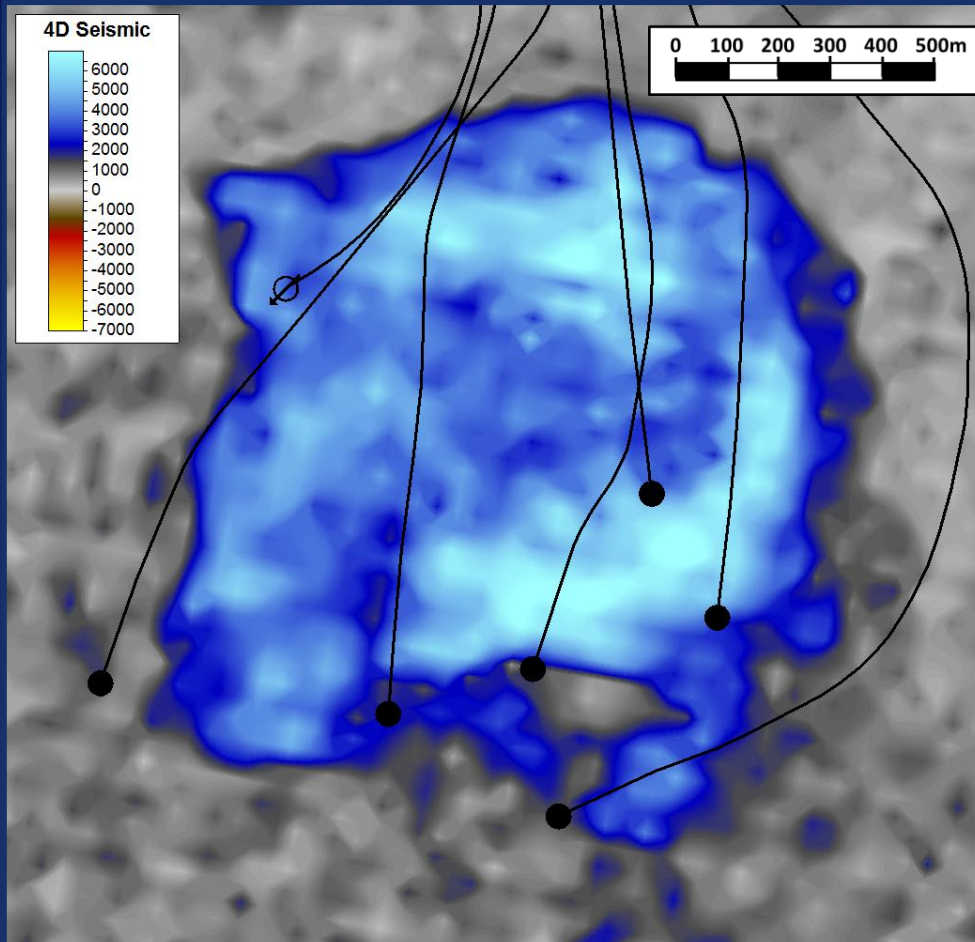


4D ASHM – Harding South Results

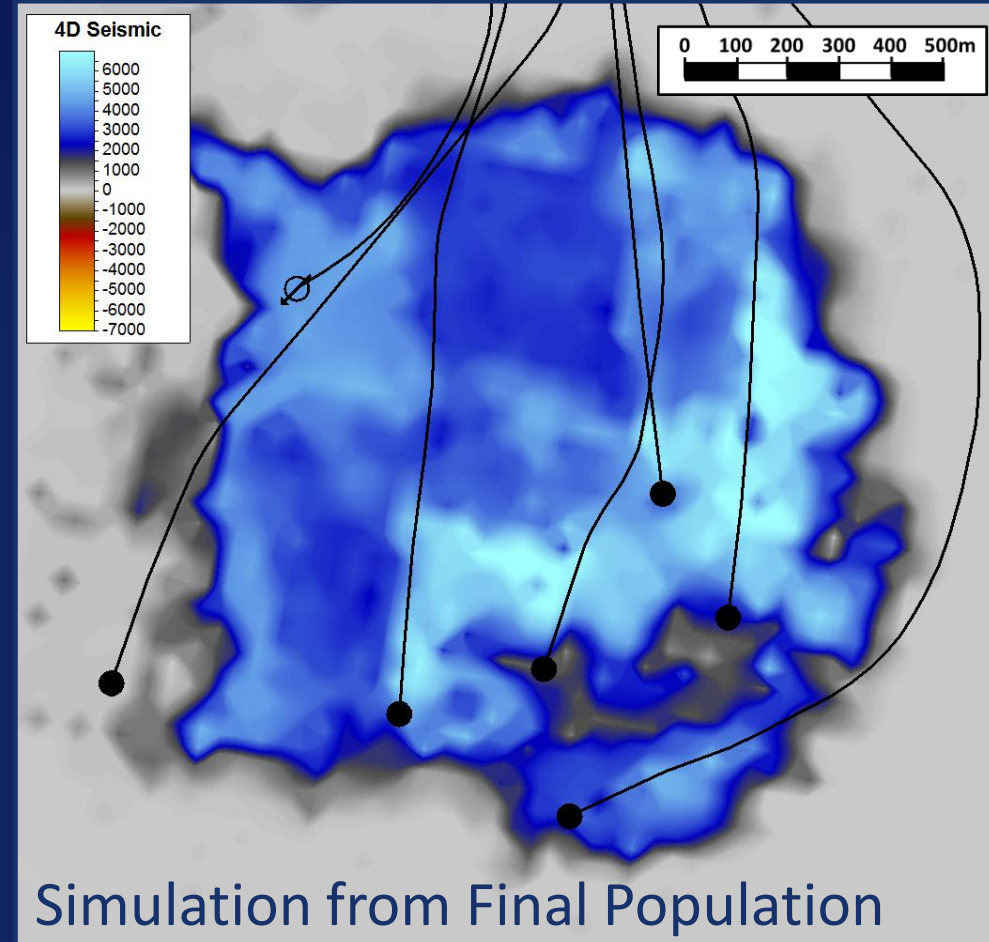


4D ASHM – Harding South Results

Real 4D Seismic Attribute Map

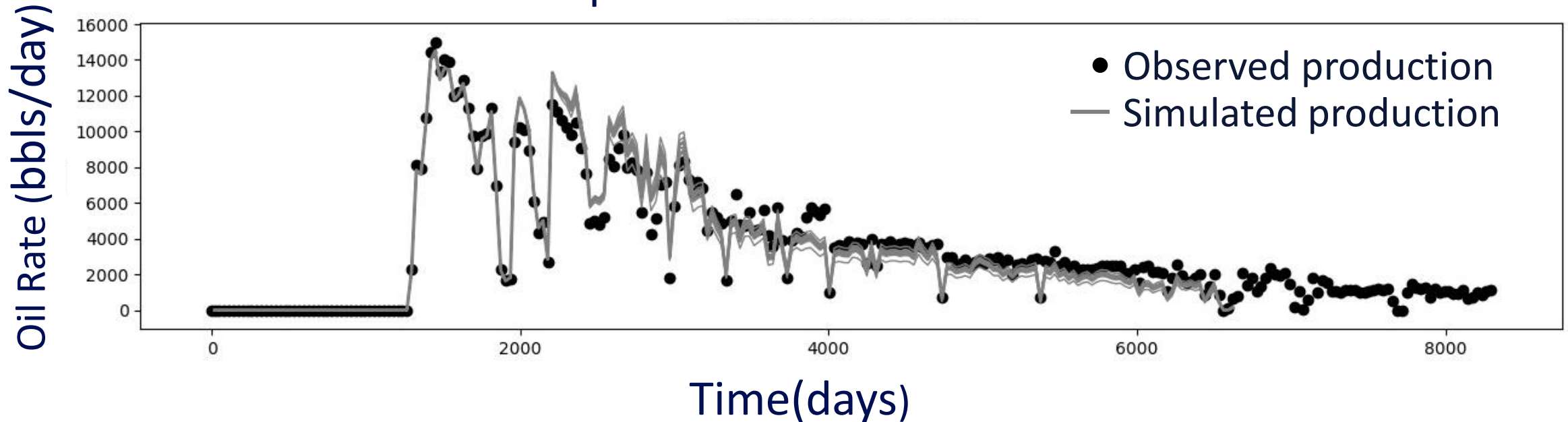


Model 4D Seismic Attribute Map



4D ASHM – Harding South Well Results

Final Population Oil Production Rate



4D ASHM using seismic improved production history match

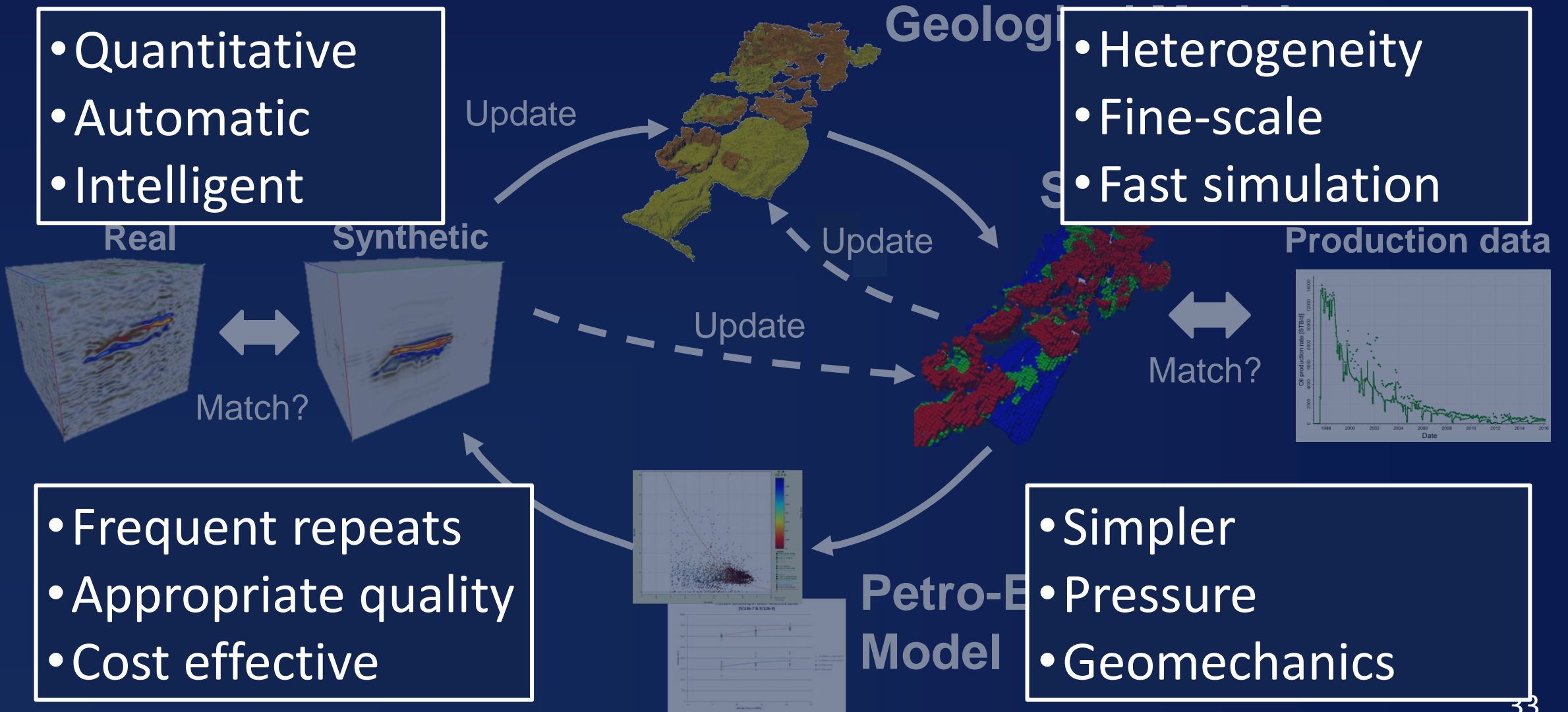
Future Directions for SHM

- Quantitative
- Automatic
- Intelligent

- Heterogeneity
- Fine-scale
- Fast simulation

- Frequent repeats
- Appropriate quality
- Cost effective

- Simpler
- Pressure
- Geomechanics



Summary and Conclusions



- Seismic History Matching (SHM) uses 4D seismic data for improved reservoir models
- It describes the dynamic behaviour of the reservoir and the underlying geology
- It is an evolving technology that integrates all aspects of reservoir description

Your Feedback is Important

Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation

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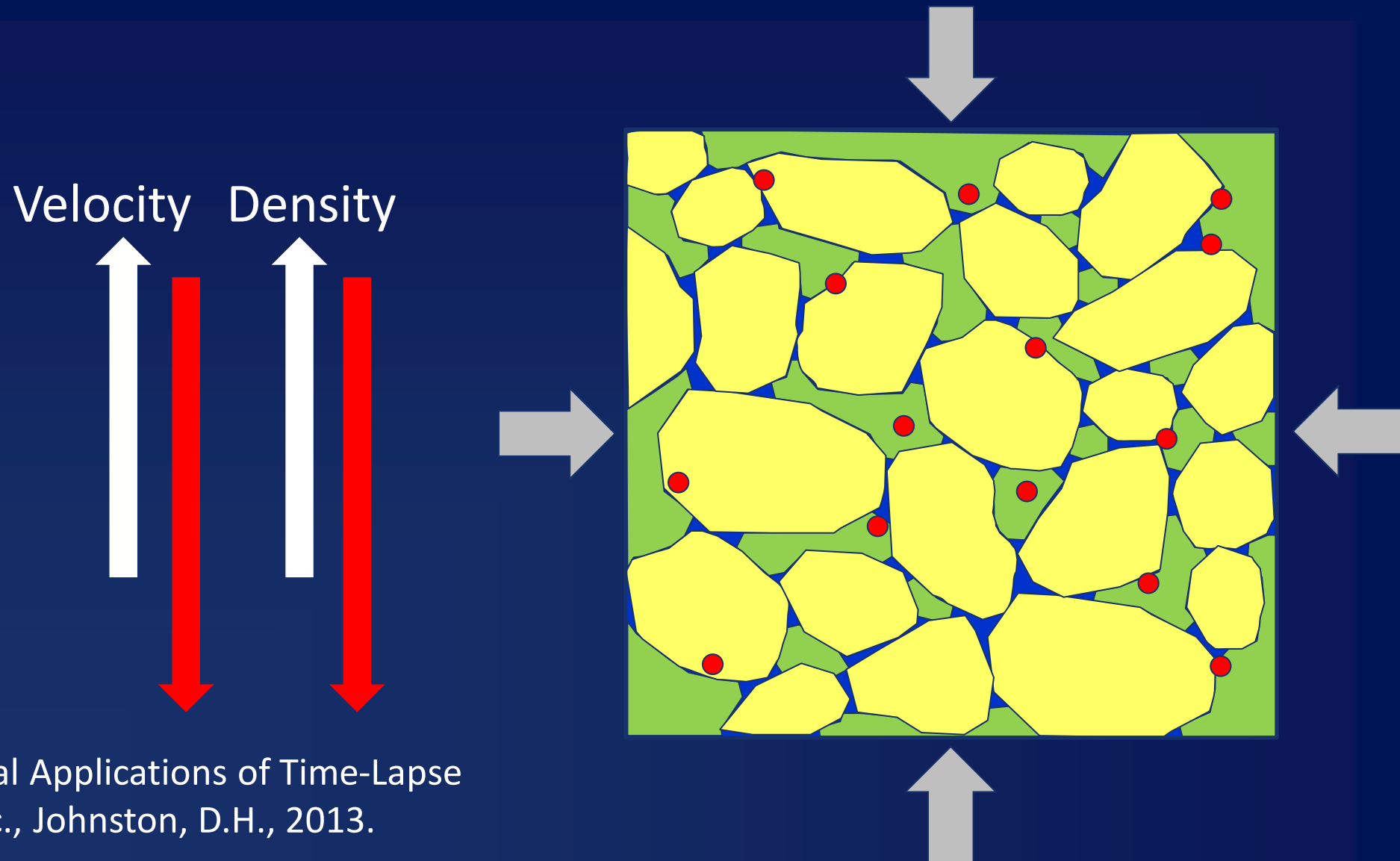
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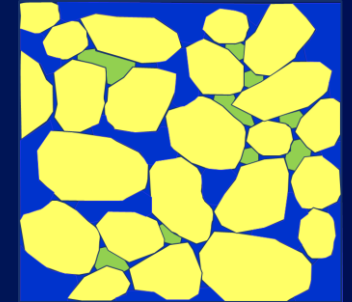
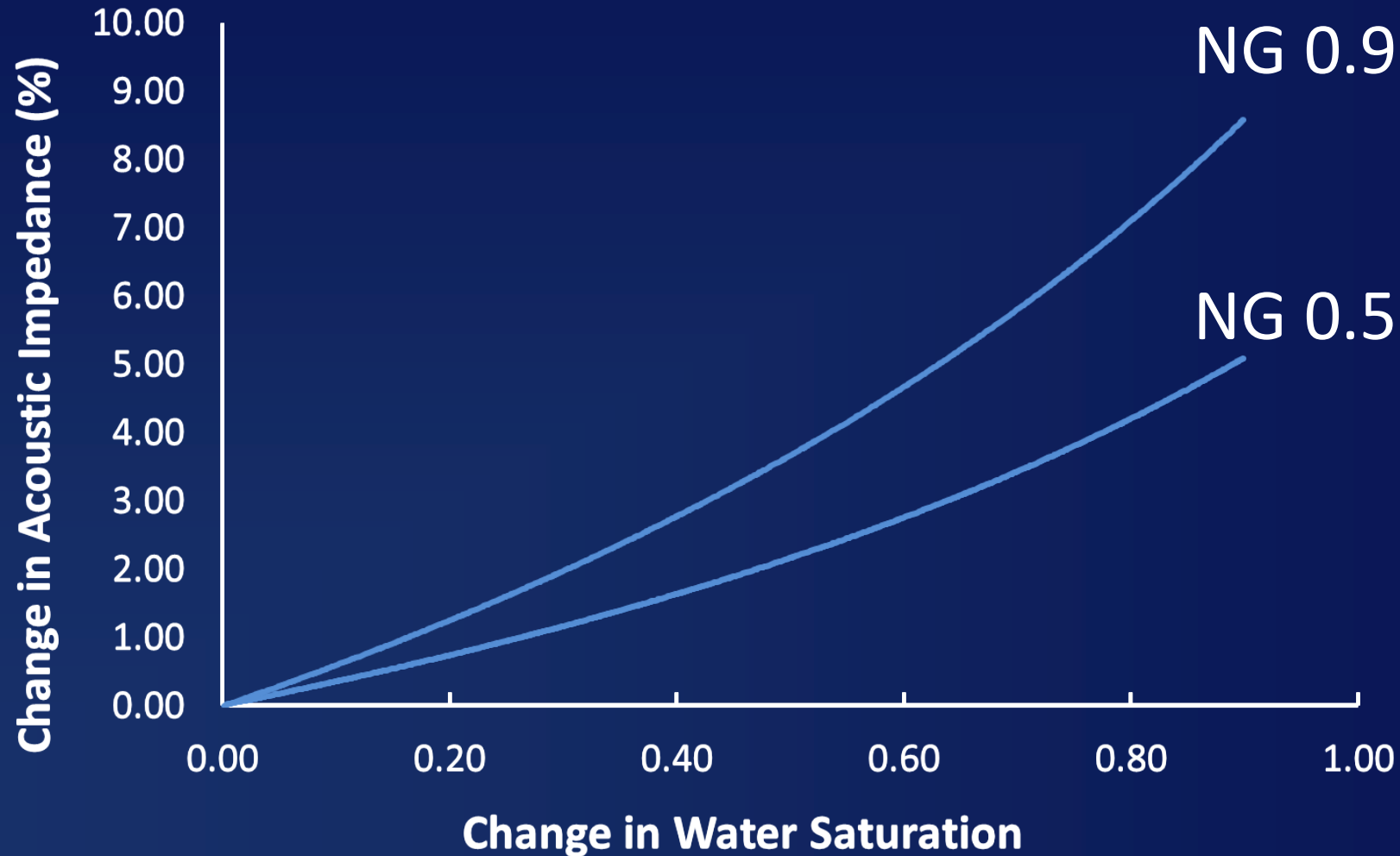


How Does 4D Work? Pressure...

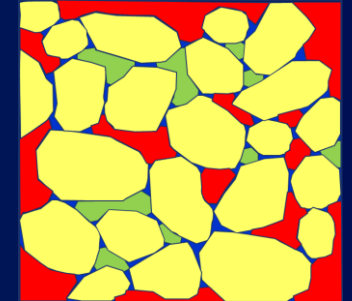
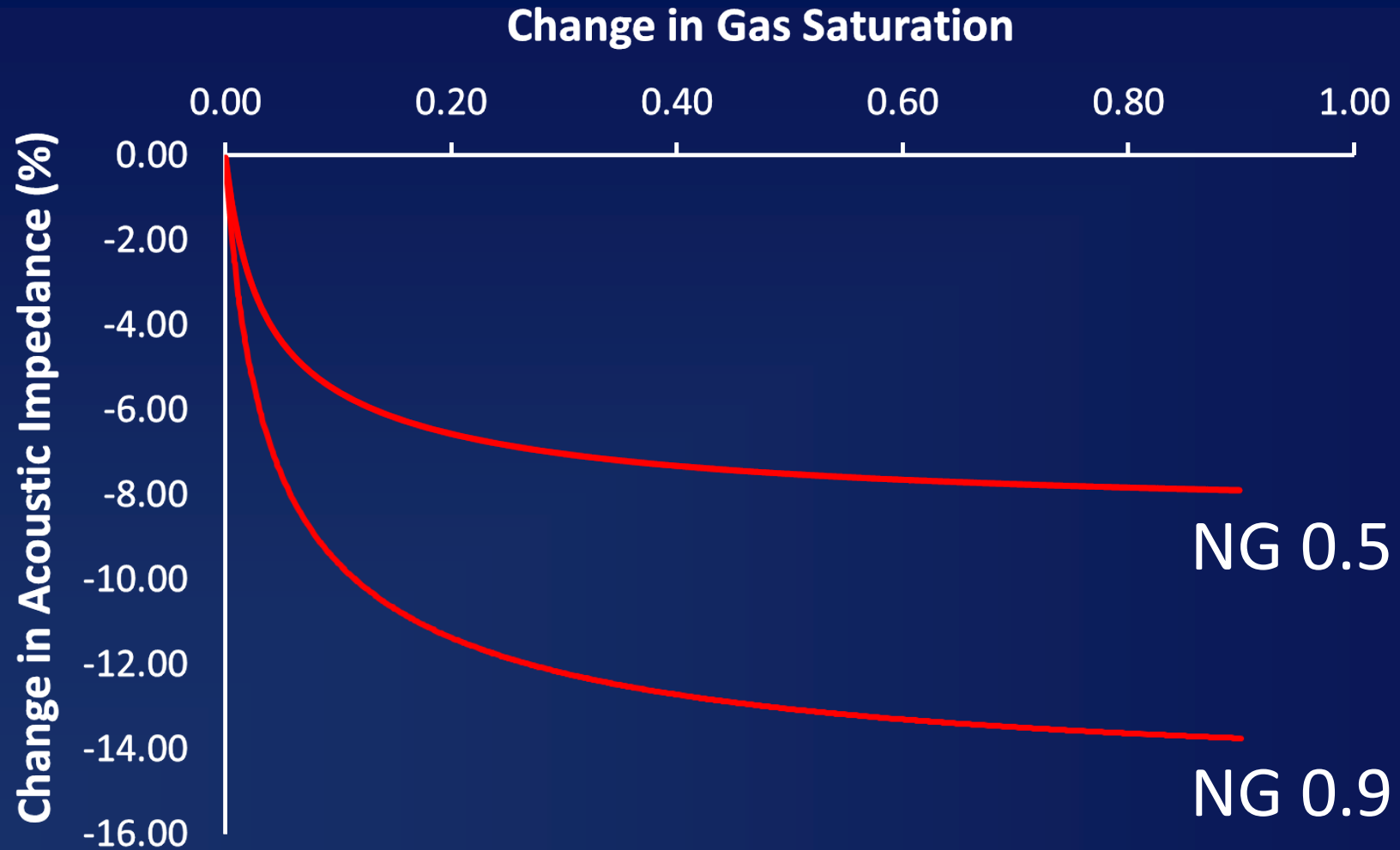


Practical Applications of Time-Lapse
Seismic., Johnston, D.H., 2013.

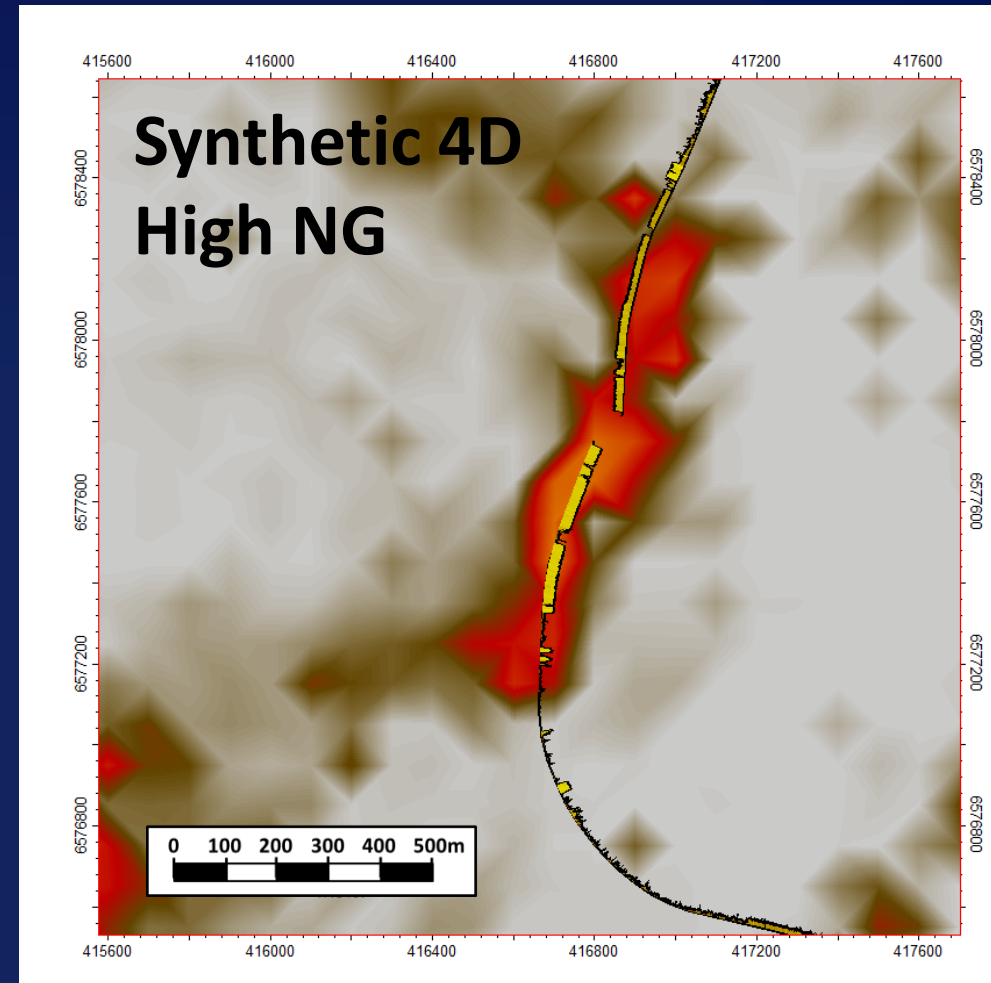
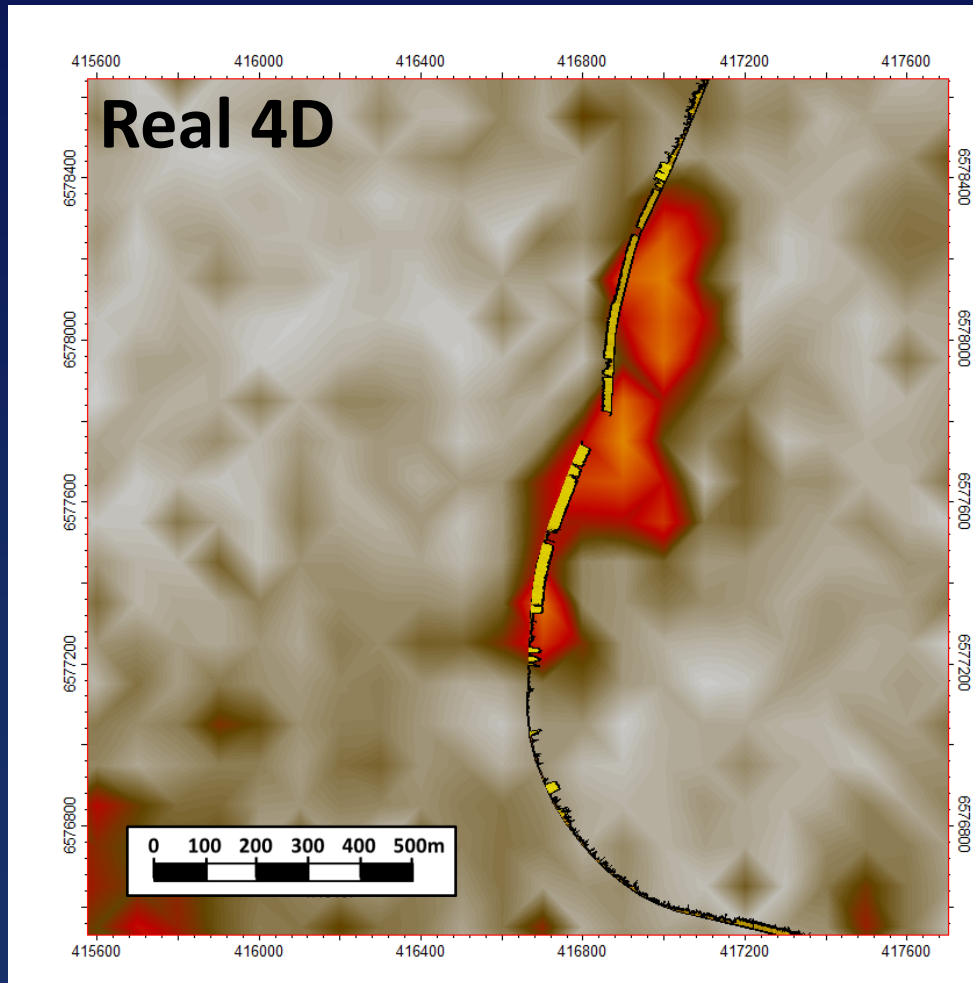
The Sensitivity of 4D – Water Sweep



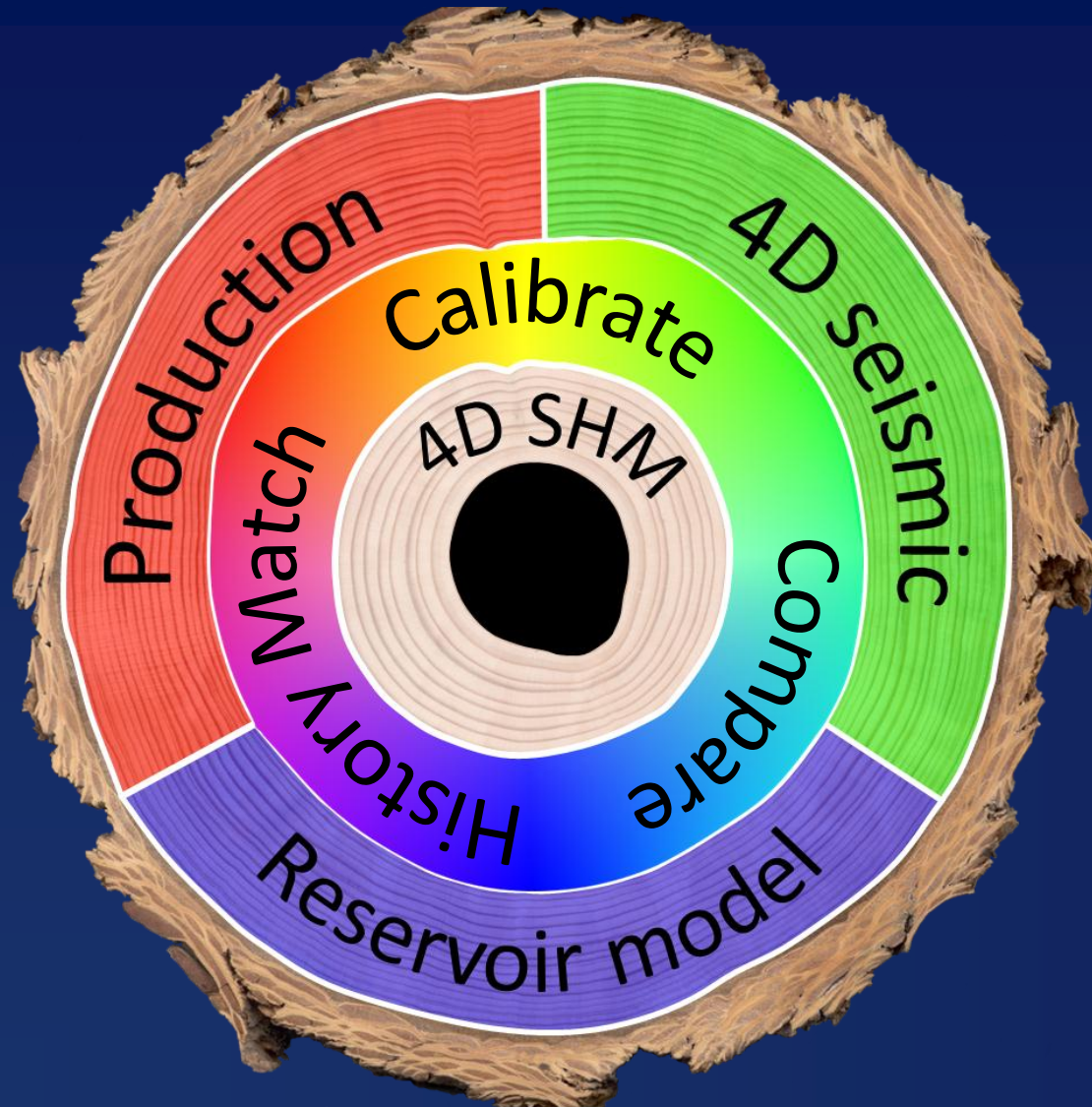
The Sensitivity of 4D – Gas Sweep



The Sensitivity of 4D – Harding North



A Tiered Approach to 4D SHM



- Assessment
- Data analysis
- Data integration
- Seismic history matching

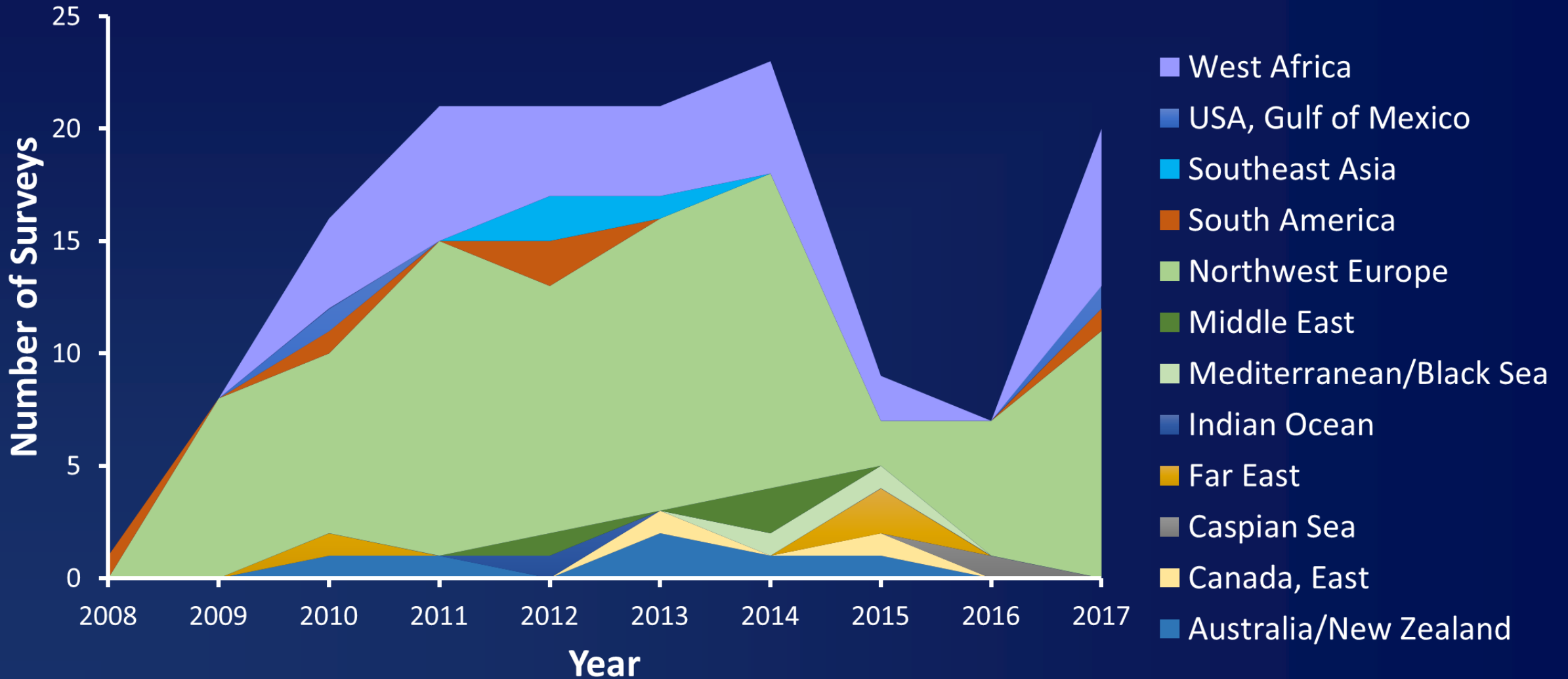
A tiered approach to 4D seismic data interpretation, Amini, H., ETLP Sponsors' Meeting, Nov 2017.

Global 4D Seismic Activity, 2008-2017



Source: SeismicBase by
IHS Markit

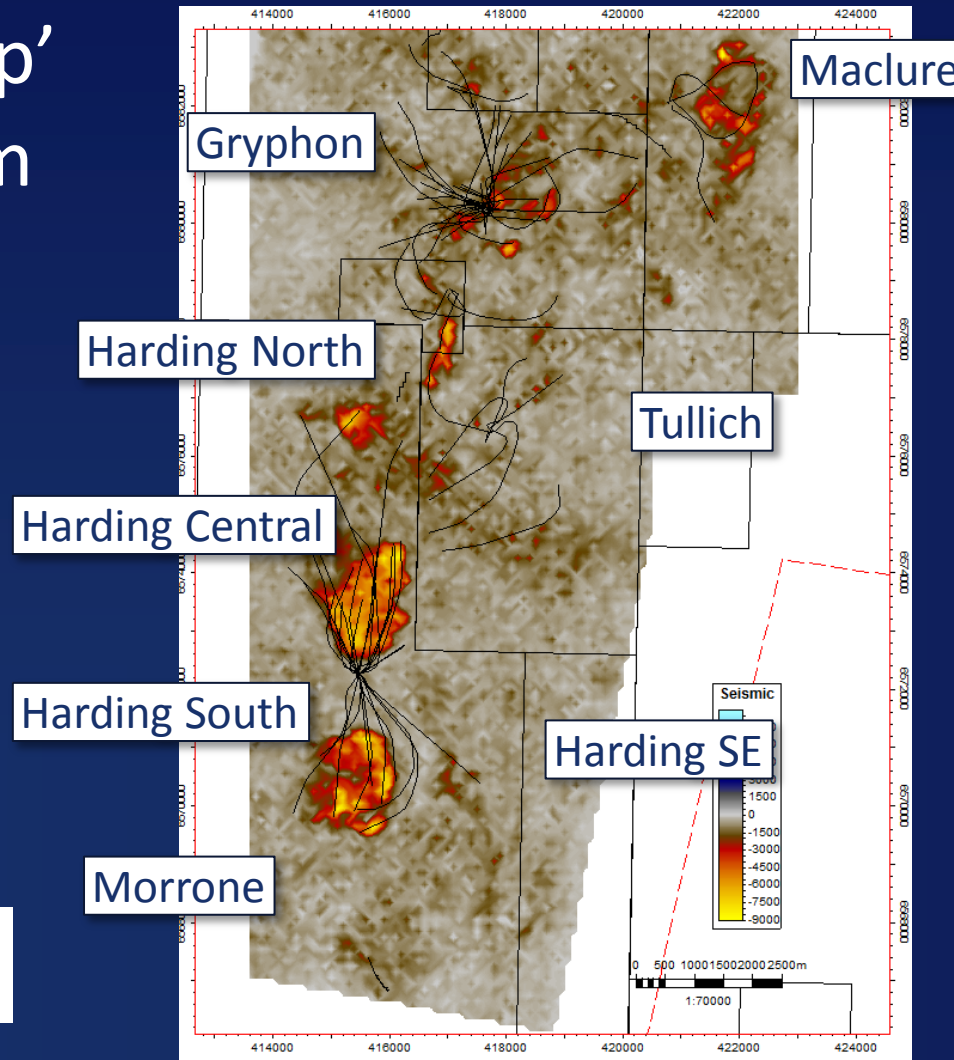
Historical 4D Seismic Activity



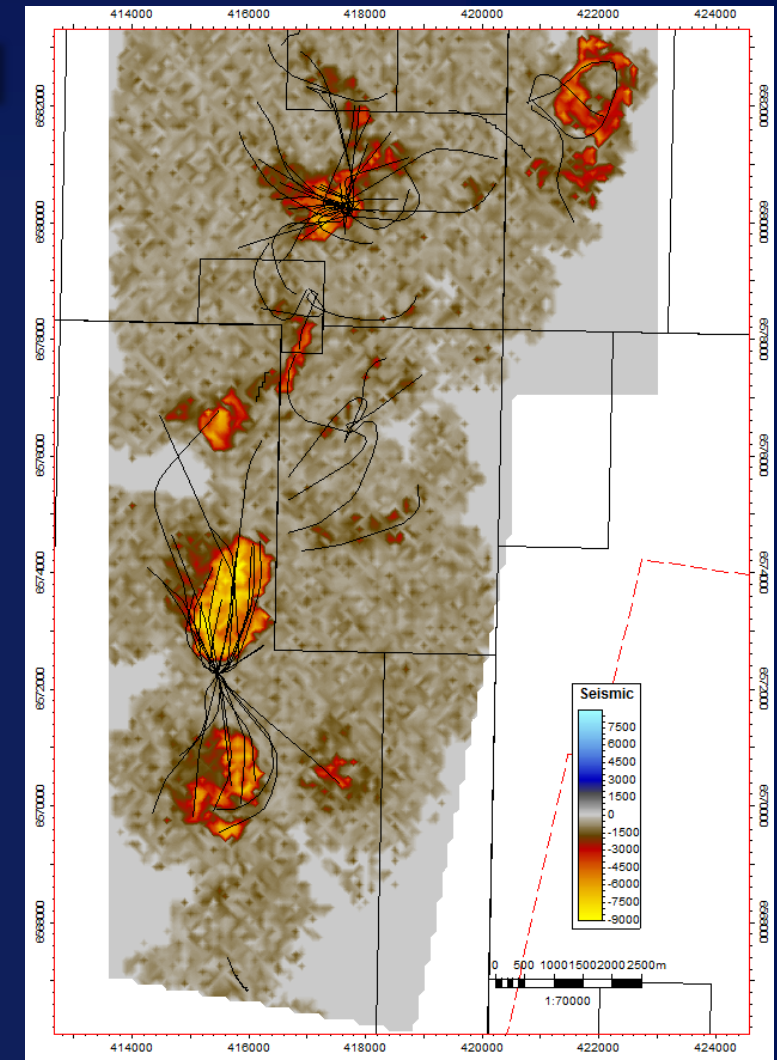
4D 'Gas Sweep' Attribute Maps

- 4D 'gas-sweep' attribute from 4D data
- Good match between real and model data

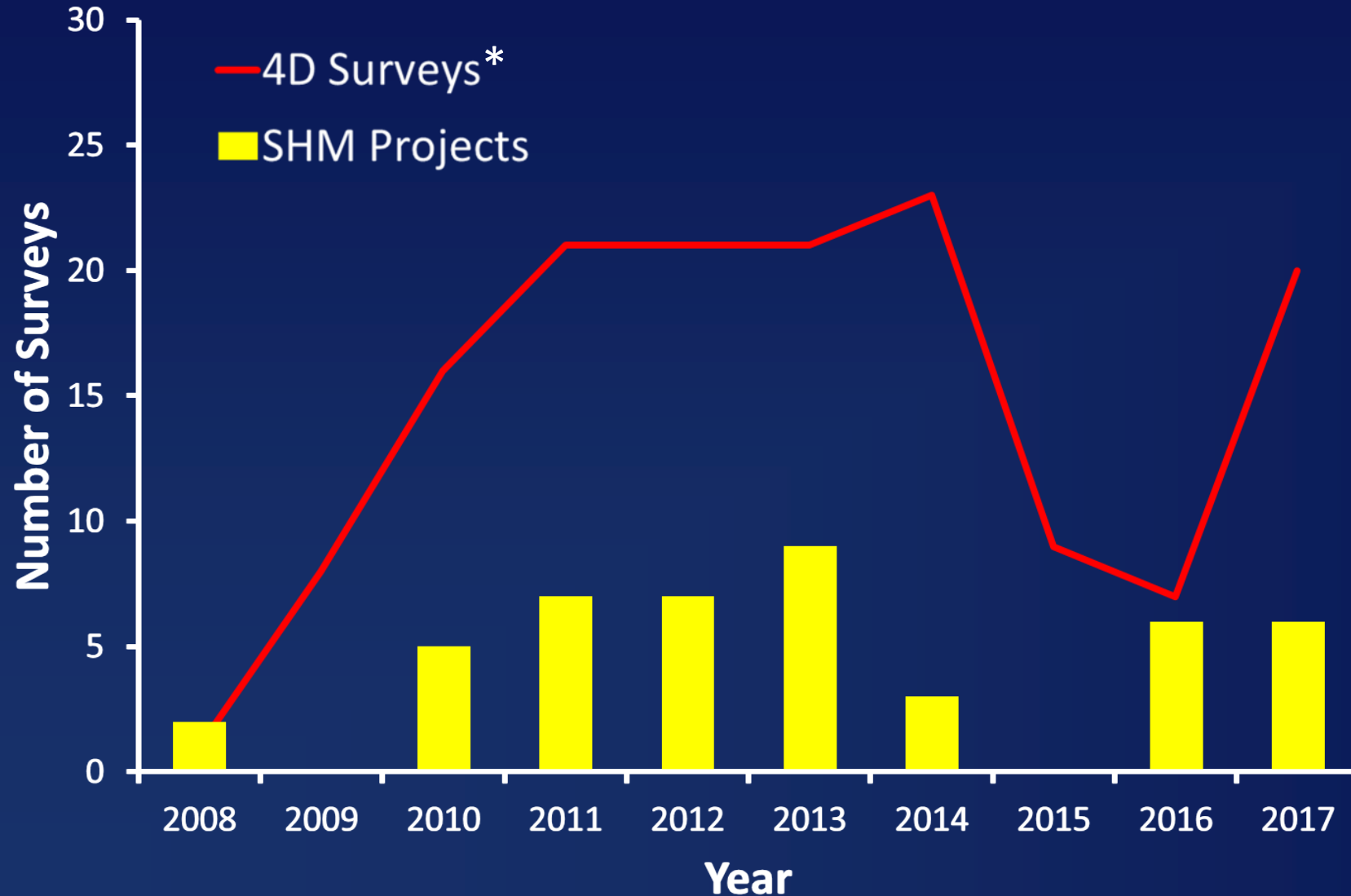
Real 4D Data



Modelled 4D Data



The Value of 4D SHM



- \$1-2bn annual spend on 4D seismic globally
- Greater value can be extracted from the data

* Source: SeismicBase by IHS Markit